

## **Appendix A:**

# Purpose and Need Support

## Appendix A:

---

# Purpose and Need Support

## **Appendix A**

### **Purpose and Need Support**

---

- Appendix A-1: Review of Denver Water's IRP, Technical Memorandum, prepared by Harvey Economics, January 15, 2004.
- Appendix A-2: Supplemental Evaluation of Denver Water Demand Projections, Technical Memorandum, prepared by Harvey Economics, August 12, 2004.
- Appendix A-3: Solutions: Saving Water for the Future. Information and Contents Regarding Conservation and Water Management Techniques. A 2011 Denver Water publication.
- Appendix A-4: Summary of 2002 Demand Model Update, Technical Memorandum, prepared by Mary Price, Demand Planning, Denver Water, April 2, 2012.
- Appendix A-5: Update of Denver Water Demand Projections, Technical Memorandum, prepared by Harvey Economics, April 2, 2012.

## **Appendix A**

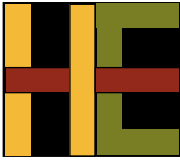
### **Purpose and Need Support**

---

*This page intentionally left blank*

**Appendix A-1**  
**Review of Denver Water's IRP, Technical Memorandum,**  
**prepared by Harvey Economics, January 15, 2004**





Harvey Economics ♦ 600 South Cherry Street, Suite 220 ♦ Denver, Colorado 80246  
tel. 720.889.2755 ♦ fax 720.889.2752 ♦ www.harveyeconomics.com ♦ he@harveyeconomics.com

## **MEMORANDUM**

TO: PAULA DAUKAS, URS AND CHANDLER PETER, USACE

---

FROM: ED HARVEY, HARVEY ECONOMICS

---

DATE: 15 JANUARY 2004

---

RE: REVIEW OF DENVER WATER'S IRP

---

This memorandum offers a review of certain elements of Denver Water's February 2002 Integrated Resource Plan (IRP). This review was prepared by Harvey Economics for use by URS and the U.S. Army Corps of Engineers (Corps) as part of the evaluation of the Purpose and Need statement that will be incorporated into the Moffat Collection System Project EIS. This memo is in partial satisfaction of Task 1b of Phase II of this EIS preparation effort.

The primary goal of this review is to determine the validity of the water demand forecasts produced through Denver Water's most recent IRP process as a basis for establishing a need to develop new firm yield supplies. This memo will answer the following questions:

1. What is the basis for the water demand projections that Denver relies upon in its planning process?
2. Is the methodology used to develop those demand projections appropriate for the purpose of formulating future water resource development strategies?
3. Was the forecasting methodology properly applied?
4. Are the data sources that drive the water demand forecasts appropriate for the purpose of producing water demand projections?
5. Are the underlying assumptions in the forecasts reasonable?
6. Based upon the answers to the foregoing questions, do the demand projections provide a sufficient basis for determining future water development requirements?

The focus of this inquiry was upon the near-term water demand projections that span from 2000 to 2030; projections to 2050, which were included in the February 2002 IRP, are not relevant to this inquiry.

Our scope of work does not include an evaluation of alternatives to meet future demands that Denver Water will face. The amount of water that might come from nonpotable reuse or system refinements, for instance, is not evaluated, so the amount of new firm yield that must be

developed is not a part of this evaluation — with one exception. This memo does include an evaluation of conservation potential as evaluated in the IRP process.

The data sources for this evaluation were limited to the IRP documents and information that supported the IRP, including the main report, entitled *Water for Tomorrow*, and the appendices devoted to water demands and conservation. All of these documents were published in February 2002. The judgment, evaluation and conclusions reached in this memo are based on the past experience of the Harvey Economics authors.

## **Overview of Denver Water's Demand Forecasting Effort**

Denver Water utilizes the IRP as a planning process that examines future water needs and available water supplies to determine net water requirements that must be met through some actions undertaken by the water utility. Alternative strategies for meeting those future net water requirements are then developed through an inclusive process that includes the public and interested parties, as well as the Denver Water staff and the Denver Board of Water Commissioners. The water demand projections are only one part of this effort, but they are vitally important in establishing the magnitude and the timing of net future water requirements beyond the existing supply. The Denver Water Board first embarked upon the IRP process in 1994, completing this first IRP in December 1996. In 2000, Denver Water initiated an update of this IRP, which culminated in a February 2002 report.

The water demand projections are composed of four basic elements:

- treated water projections for Denver Water's water service area (WSA). This term includes the City and County of Denver, the total service districts, the read and bill districts and the master metered districts, but exclude those entities that have special commitments or fixed contracts with Denver Water;
- a deduction for the natural replacement of water conserving plumbing appliances;
- contractual water service commitments outside the WSA boundaries; and
- the addition of a safety factor.

Accounting for all these factors, Denver Water derived a final demand forecast of 450,000 acre-feet at buildout, which Denver Water expects will be reached by the year 2050. Denver Water defines near-term needs as those evident by the year 2030, which are estimated at 406,000 acre-feet. Compared with Denver Water's present firm annual yield estimates of 375,000 acre feet, this estimate suggests net new requirements must be met by the year 2030. Each of the components of these demand projections is evaluated below.

## **Denver Water's Demand Forecasting Model**

Denver Water's demand projections begin with the treated WSA forecasting model developed by BBC Research & Consulting (BBC), which was completed in 2001. This forecasting model is composed of three sub-models: the single family household forecasting model; the model projecting water demands from multi family households, commercial and industrial customers; and a model that projects institutional water demands. Each of these three models is represented by separate econometric equations wherein, for example, single family water use per household

is a function of a set of independent variables, such as household income, residential density and water price. Each of the independent variables must be projected over the forecast period and applied to the equation in order to produce a projection of single family household water use per household. This water use factor is then applied to a projection of single family households to develop total forecasts of single family water use. The other two submodels are structured in a similar manner. Exhibit 1 provides each of the three model specifications.

**Exhibit 1.**  
**Denver Water's Demand Forecasting Models**

**Single Family Water Consumption Per Account =**

1.78 (median household income, in \$1,000's) - 6.06 (district residential density per acre) - 2.17 (precipitation inches between May and September) + 22.1 (average persons per household) - 76.1 (proportion of metered single family households) - 9.42 (marginal water cost per 1,000 gallons) - .0217 (average conservation expenditures over a three-year period) + 186 (constant)

**Total Commercial, Industrial and Multifamily Water Use =**

33.5 (employment, in thousands) + 7.3 (multifamily households, in thousands) - 7.59 (precipitation inches between May and September) + 337 (constant)

**Total Institutional Water Use =**

9.07 (employment) - 61.6 (precipitation inches between May and September) - 702.1 (marginal water cost, in thousands)

Source: BBC memo to Denver Water, October 31, 2001.

Economic and demographic projections are applied to each of these three models to produce demand projections for the three categories. The demand projections from the three models are then added together to arrive at total treated WSA demand projections.

**Evaluation of the Methodology.** The BBC models can be characterized as econometric, statistically derived, regression models. They are cross-sectional time series models, also referred to as panel models, derived using regression analyses. The cross sections are the various water providers that Denver Water serves, and the time series covers a period from 1973 through 1999. The independent variables, such as water price, are both consistent with theory and verified through regression analysis, which is used to explain variations and to predict the dependent variable, water use. The independent variables were selected from water demand forecasting literature in the public domain, reviewed by BBC and documented in a November 1, 2000 memo to Denver Water.

BBC is correct in pointing out that this econometric approach to water demand forecasting is sophisticated and state of the art. For many past decades, water demand was projected by either extrapolating historical trends or applying an assumed, all-encompassing, water use factor such as gallons per capita per day. In locations with larger and more diversified economic and demographic activity and with sufficient historical data, the econometric approaches like those employed by BBC are considered appropriate and desirable. The most common of these models, the IWR-MAIN model, is widely used for metropolitan areas, and it employs multi-variate regression analyses, resulting in equations similar to those developed by BBC. The Corps adopted the IWR-MAIN water use forecasting system and applies it in those planning

studies where such an approach is possible and appropriate. The drawback to these models is the requirement for voluminous and accurate historical data necessary to conduct meaningful regression analysis.

The selection of variables utilized in the BBC model — income, persons per household, price and weather — has a theoretical underpinning in other demand forecasting models, and all are evident in the econometric models used in most other cities. Other independent variables in similar models elsewhere, such as house size, lawn size, number of bathrooms or house value, are not evident in BBC's final econometric models. BBC tested additional independent variables in its regression analyses but found them to be statistically insignificant. For other potential independent variables, like other price variables, accurate historical data was not available in a cross section or time series format to apply to the BBC model. Although it would have been preferable to have tested many more independent variables, the statistical validity of the models produced supports the selection of these four particular independent variables. In essence, the key independent variables in the literature were tested and employed by BBC in its final econometric model specifications. The dependent variable in the literature is almost always water use or total water use, similar to BBC's approach.

The final Denver Water forecasting models are refinements of similar models that were extensively reviewed as part of the Two Forks EIS. A number of independent experts reviewed and contributed to these models, agency and public suggestions were considered, and final models were adopted by the Corps for that effort. Denver Water has relied on earlier versions of the current model for years.

In sum, the methodology for arriving and specifying the demand forecasting model should be considered appropriate and acceptable for Denver Water's water demand forecasting purposes in its IRP.

**Application of Methodology.** Denver Water and BBC worked together in the development and implementation of the demand forecasting models. For instance, BBC indicated the water use data that would be required to perform the cross sectional, multi-variate regression analyses, and Denver Water collected the data.

The regression analysis was reportedly performed utilizing standard regression techniques. A host of independent variables were tested using linear, log, and double log specifications. The final selection of the variables was based upon proper techniques, including statistical and theoretical tests for variable significance. Finally, the models were tested and corrected for autocorrelation and heteroscedasticity. Each independent variable was evaluated for spurious correlation and for the theoretically correct signs in front of the coefficient. Dollar-denominated independent variables were properly corrected for inflation.

BBC points out the uncertainty of interpreting the water conservation variable in the demand forecasting models. Although the variable is statistically significant, there are no specific programs, beyond metering, price increases and the natural replacement of plumbing fixtures, known to have been undertaken by Denver Water that have produced such savings. BBC suggests that the water conservation variable might reflect an emerging general conservation ethic on the part of water users in the Denver metropolitan area. In fact, recent Denver Water surveys have indicated that 90 percent of Denver Water's customers understand that conserving water is a valuable and desirable goal. Going forward, the demand forecasting models assume

that an inflation adjusted, constant level of conservation expenditures will continue to produce past conservation savings. According to outside experts, the “low hanging fruit” of conservation savings have already been achieved, and further conservation savings are considered separately in the IRP planning process.

In sum, the application of the forecasting methodology is considered acceptable and reliable.

**Data sources.** The historical data sources that BBC relied upon in the development of the water demand forecasting model were drawn from Denver Water, the U.S. Census Bureau, the Denver Regional Council of Governments (DRCOG) and the Colorado Department of Local Affairs (DOLA). The data collection effort required for a cross sectional time series model is significant.

The most critical data collection effort was the gathering of the dependent variable information related to water use, by consumer category, by water provider and by year. Denver Water was tasked with providing water use data for all of the water distributors within its service area from 1973 through 1999. An attempt was made to gather data for 55 water districts over 26 years, which would have produced 1,430 total observations of water use. In fact, only 834 cells of water use information were identified for the single family model, and fewer observations were found for the commercial and institutional water use models. Although the data gathering results were less than ideal, the number of observations that were provided is quite large and more than sufficient for credible regression analysis. It must also be recognized that Denver Water and its consultants went to great lengths to gather accurate historical water use data, including a survey of Denver Water’s master metered districts.

The data sources for the independent variables in the model, including median household incomes, persons per household, single family versus multi family households, and employment, were mostly drawn from standard sources, including the U.S. Department of Commerce and the U.S. Census Bureau. DRCOG allocated these economic and demographic data sources to small geographic areas known as traffic analysis zones. These traffic analysis zones were then aggregated to water distributor service boundaries for incorporation into the model. Residential density figures were obtained from individual planning agencies throughout the Denver area, supplemented by DRCOG and Census information. Precipitation data were forthcoming from Federal weather monitoring authorities. The marginal cost of water was determined using the rate structures of each water distributor and their average water use. Conservation expenditures were forthcoming from Denver Water. These historical data sources are commonly accepted and appropriate.

**Validation of model results.** Several methods were implemented to evaluate the validity of Denver Water’s demand forecasting model. The statistical measures associated with each of three sub models suggest that they are valid.

Each independent variable was tested for statistical significance following standard statistical practices. All of the independent variables in each of the models were found to be statistically significant at either the 95 percent or 99 percent level. The various models’ overall predictive capability predictions are also relatively strong. The single family model has an  $r^2$  of 0.65, the commercial model has an  $r^2$  of 0.99 and the institutional model has an  $r^2$  of 0.92. Each of the models was tested for standard forms of bias, such as auto correlation and heteroscedasticity and corrected as needed.

The models were also subjected to backcasting. That is, each was used to project historical water use each year from 1973 to the year 2000. The model appeared to over-predict water demand from 1973 to 1984 and to under-predict demand for 1985 through 2000. The average under-prediction of the past 15 years was five percent. This five percent figure was used to upwardly adjust this model for the systematic error. This adjustment is appropriate given that the past 15 years are likely to be more representative of the future than the earlier period. Overall, the model's backcasting average suggests a maximum over-prediction of about 14 percent and a maximum under-prediction of about 10 percent, which is considered reasonable for the 27-year period.

BBC also performed a sensitivity analysis on the model. The sensitivity analysis changed the independent variable assumptions to a high and low scenario and found that the range of potential error is only about 10 percent, suggesting a model relatively insensitive to erroneous assumptions.

**Conclusions about the demand forecasting models.** Denver Water's demand forecasting models, as utilized in the February 2002 IRP, are considered appropriate for this purpose. The methodology employed meets the standard of modern demand forecasts in other metropolitan areas and follows the trends in the water demand literature. The application of this methodology also appears to be appropriate as it has been described in the supporting document of the IRP. Standard data sources were utilized with a proper testing of the model for validity, and adjustments to the model on the basis of those tests that were appropriately performed.

## **Economic and Demographic Data and Forecasts**

The demand forecasting models are driven by and specified on the basis of economic, demographic and socioeconomic information. Population, households and employment projections for the region are applied to the models to produce treated WSA demand projections. The economic and demographic projections also determine where that growth will occur, which is important because the Denver Water service area is only part of the full eight-county Denver region.

The economic and demographic projections applied in the 2002 IRP were a combined effort by the Center for Business and Economic Forecasting, DRCOG, the Colorado State Demographer and BBC. DRCOG led the economic and demographic forecasting effort for the year 2000 through 2020 period through collaboration with the Colorado State Demographer. BBC extrapolated DRCOG forecasts from the year 2020 to 2030, the end of the near-term forecasting period.

**Methodology.** The DRCOG regional economic and demographic forecasts include a demographic model and an economic model that are linked together through labor force participation rates that drive sections of migration into the region. This forecasting technique has been used by DRCOG for decades, but the model structures and the assumptions have been updated and refined to reflect historical conditions.

The economic model as developed by the Center for Economic and Business Forecasting produces employment forecasts for the eight-county Denver region on the basis of state and Federal projections. The Federal projections are Standard & Poor's DRI projections, which require a host of important economic assumptions. The national economic forecast is used to

produce state and Denver regional employment projections by assuming that the historical relative advantages that Colorado's and Denver's economies enjoy, as compared with the U.S., will continue. The Denver regional forecasts produce labor force requirements that are related to population by a labor force participation rate, or the percentage of people available for work among the population.

The demographic model is a cohort-component type model that looks at births and deaths by age category and projects population dynamically over time. To the extent that these natural population changes are insufficient to meet labor force requirements, additional population is assumed to in-migrate to meet this labor demand. The migration is then factored into the population base for subsequent natural population changes as the forecasts progress over time. In terms of methodological structure, this type of economic and demographic forecasting is commonly used and widely accepted.

**Application of the methodology.** DRCOG applies the economic and demographic forecasting methodology in a very open and inclusive process. First, an Economic Forecasting Task Force (Task Force) is appointed from among regional experts to consider and suggest changes to the forecasting drivers, mainly the assumptions underlying the projections. In addition, DRCOG works with the State Demographer to coordinate state and regional projections for consistency purposes. In addition, DRCOG seeks out development and planning information from virtually every community in the Denver metropolitan region to provide information and suggestions and to hopefully support the final forecasts. These diverse inputs are considered in modeling the final projections.

In the past, DRCOG was subjected to pressures from local governmental entities with growth agendas that might have been inconsistent with more reasonable overall assumptions. This regional planning agency has worked hard to overcome this bias by focusing on a consistent consensus from among the larger group. With these refinements over the years, DRCOG's long range economic and demographic forecasting process has improved and is considered appropriate for use in the IRP projection process. Besides water utility planning, the DRCOG forecasts are used for essentially all major infrastructure planning in the Denver region by all levels of government.

**Assumptions and data sources.** The most important consideration in evaluating DRCOG's projections are the underlying assumptions that drive the projections. These assumptions include:

- U.S. employment forecasts call for an increasing full employment growth path consistent with baby boom retirement.
- Fiscal policy is consistent with recent government projections, assumed to be expansionary.
- Demand for goods and services will focus more on consumption in future years, and less on investment, as baby boomers retire.
- The Colorado economy will continue with its historic relative economic advantages of lower cost of living, quality of labor force, rising productivity rates and desirability of living conditions as compared with the nation.

- State and Denver regional economic growth will remain on a parallel path for the foreseeable future.
- Fertility rates and life expectancy rates for the nation, state and the Denver region are expected to level off and maintain historical relationships.
- The growing number of 60-year-old and older individuals will continue in the Denver region. Conversely, the Task Force suggested that aged persons over 75 will seek to be near their middle-aged children, perhaps moving out of the region.
- Household formation in the Denver region will follow national and state trends.
- Labor participation rates will fall along with the aging of the population.
- These projections assume continuing availability of all utilities and infrastructure, including water.
- No growth controls are mandated for the Denver region.
- No economic shocks, such as earthquakes or wars, are assumed.
- Economic cycles are ignored in these long-term forecasts.

These assumptions were extensively reviewed and commented on in an open process by the Task Force and others in the region. There is no basis for asserting that these assumptions are unreasonable and, therefore, may be accepted for the purpose of developing these economic and demographic forecasts with one exception. DRCOG forecasts assume a Federal budget surplus over the next 10 years, which is unlikely to occur according to the most recent projects projections of government fiscal planners. It is uncertain how this errant assumption will affect the overall projections, however.

With these extensive major assumptions and other minor assumptions, the uncertainty of the projection is evident. It is unknown whether these assumptions, however reasonable, will come to pass. It is highly unlikely that even most of them will, but there is a tendency for offsetting errors and assumptions to limit the effect on overall forecasts. In other words, one wrong assumption will tend to drive the projections lower while another wrong assumption will tend to drive the projections higher, offsetting one another.

**Extrapolation of the 2020 DRCOG Projections.** BBC extrapolated the DRCOG projections of economic and demographic activity by assuming a relationship of Denver area growth to growth throughout the U.S. Historically, average annual population growth in the Denver area has been higher than national growth. For example, average annual growth in the Denver area was 2.0 percent from 1990 to 2000, whereas growth nationwide was 1.2 percent. DRCOG projects average annual growth of 1.6 percent between 2000 and 2020, whereas national projections from the U.S. Census Bureau suggest a 0.7 average annual growth rate during that same period. BBC assumed for its extrapolation that the Denver area would grow at the national growth rate according to the Census Middle Series plus 0.25 percent. Since this rate is slower than historical differences, it may be considered reasonable. The extrapolation of household size was based upon historical averages for household size which have remained

steady at about 2.3, and the single family versus multi family housing unit split was based on a 50 percent split between single family and multi family households that is consistent with past trends. Employment projections were based upon a job-to-household ratio following past trends. Income projections were also based upon past income growth, which averaged 0.4 percent per year. On the whole, these extrapolation assumptions from 2020 to 2030 appear to be reasonable.

**Spatial Aspects of Growth.** Denver Water's demand forecasts are also driven by the location of growth. The Denver WSA and the other water entities that have contracts with Denver Water tend to be focused in the central area of the Denver region. DRCOG assumes that growth will be relatively higher in this central region of the Denver area as a result of the comprehensive planning process known as Metro Vision 2020. Many local government and other experts, including land developers, were involved in suggesting where growth might take place. The culmination of this effort was a scenario of compact growth that focused on the core of the Denver region. These predictions of the spatial aspects of growth in the Denver region allowed Denver Water's demand forecasts to accurately reflect growth in the actual service area.

**Evaluation of projections.** The change in population for the Denver region is projected to be approximately 892,000 people between the years 2000 and 2020. This growth represents a total change of 38 percent and an annual average rate of growth of 1.6 percent. By comparison, DOLA predicts that population in the Denver region will grow by 872,000 from 2000 to 2020, equaling a total growth rate of 36 percent and an annual average rate of growth of 1.5 percent. In contrast, DOLA records show that population for the Denver region grew from 1.63 million people to 2.41 million people between the years 1980 and 2000 — an increase of roughly 786,000 people over the 20-year period, with a 48 percent total growth rate and a 2.0 percent annual average rate of growth.

The growth in employment in the Denver region is projected to be about 574,000 employees between the years 2000 and 2020. This growth represents a total change of 41 percent and an annual average rate of growth of 1.7 percent. By comparison, DOLA forecasts that employment in the Denver region will increase by 731,000 employees from 2000 to 2020, equaling a total growth rate of 42 percent and an annual average rate of growth of 1.8 percent. In contrast, DOLA records show that employment in the Denver region increased from 843,000 employees to 1.4 million employees between the years 1980 and 2000 — an increase of roughly 511,000 employees over the 20-year period, with a 61 percent total growth rate and a 2.4 percent annual average rate of growth.

In truth, there is little opportunity for testing the accuracy of demographic and economic forecasts. Such forecasts are inherently very uncertain, and they are based upon a host of assumptions that must be made about an uncertain future. With these caveats, the DRCOG economic and demographic projections from the year 2000 to 2020 meet the standard for these types of projections and are acceptable for application in Denver area water demand forecasting.

## **Natural Replacement Adjustment**

Following the demand forecasting model and the resulting treated WSA projections, an adjustment in the demand forecasts is made for natural replacement, the replacing old

inefficient plumbing fixtures with modern water conserving fixtures, such as low flow toilets and shower heads. These plumbing fixtures are installed in existing residential units during remodeling or when the old ones wear out. Local building codes require these new fixtures. This adjustment is considered separately from water conservation, since no action is required on the part of Denver Water or any other agency.

As described in Denver's IRP, the Denver Water demand projections are reduced by projections of natural replacement or replacement of plumbing fixtures.

The projection of potential savings for natural replacement is based upon an inventory of older water fixtures in Denver Water service area and the rate at which those water fixtures will be replaced. The inventory of older fixtures is based upon Census information about age of buildings and the rate of remodeling or replacement as monitored through building permit activity and related data collected by Denver Water.

The calculation of future natural replacement savings was reviewed by an independent consultant, Maddaus Water Management, which verified and refined the natural replacement savings projections. The projection of these savings, which amounts to 39,000 acre-feet per year by the year 2030, is considered reasonable based upon the sources relied upon for their derivation.

An important question remains about how or whether natural replacement should be incorporated into the overall demand projections. The incidence of natural replacement took place during the same historical period over which the water demand model was developed. Especially during the 1990s, the replacement of water-conserving appliances occurred frequently and was reflected in the water use estimates that were part of the demand forecasting model specification. Although no variable clearly reflects natural replacement in the model, it is quite possible that the effects of natural replacement are captured by other variables, most likely Denver Water's water conservation expenditures. If true, natural replacement is already embedded in the demand forecasts, at least to some extent, and the additional reduction for natural replacement might produce an under-forecast of actual water demand in the long-term. There is no way to determine for certain whether natural replacement should be included or excluded at this point, but it must be noted that the final near term demand forecast could well be understated for this reason.

### **Commitments to Provide Water Outside Denver Water's Service Area (Other Commitments)**

Besides Denver Water's contract with its distributors in the WSA, the utility has additional commitments to provide water to other entities outside the WSA but within the Denver metropolitan area. These commitments must be added to the demand forecasts since they are a future Denver Water obligation. There are approximately 30 entities, including municipalities, water districts, industrial customers, golf courses and power plants, that have agreements with Denver Water to provide up to a certain supply of either treated or raw water each year. In the year 2000, the total water demand from these fixed and special commitments amounted to approximately 43,000 acre-feet. However, Denver Water is committed to providing slightly more than 67,000 acre-feet, suggesting that an additional 24,000 acre-feet of demand be incorporated in the Denver Water demand projections. According to Denver Water officials,

these customers have indicated that they intend to take all of the water they are entitled to by 2030. None is interested in relinquishing their future water supply commitment.

Prudence would suggest that Denver Water prepare to meet the full commitment of these fixed and special agreements. Although the exact timing is dependent upon each entity's own desires, it is reasonable to assume that these commitments will be fulfilled in their entirety by the year 2030.

## **Safety Factor**

The fourth and final element of the Denver Water demand projection includes a 30,000 acre-foot safety factor. This safety factor is a constant figure that is added on top of the water demand projections each year. The safety factor is intended to make sure that the Denver Water Board is able to meet its charter commitment to serve all customers within its jurisdictions with water under any circumstances. The 30,000 acre-foot safety factor is intended to protect against a host of uncertainties including:

- a constriction of existing supplies;
- a downward revision in Denver Water's estimated safe annual yield due to a prolonged drought;
- the catastrophic loss of facilities;
- delays in the development of new supplies; and
- higher than anticipated demand forecasts.

There is justification for each of these factors of uncertainty. Instream flows, lawsuits or other incursions against Denver Water's existing supplies have precedent (i.e., Endangered Species Act). The drought of 2002 and 2003 has caused a number of utilities in the U.S. to reevaluate their safe annual yield. Delays in bringing new supplies online can happen. Catastrophic facility losses are, of course, possible, especially in the new era of international terrorism.

The uncertainties associated with the demand forecast must be readily acknowledged. Population and economic growth could be faster than anticipated, or it could be slower. The many assumptions behind the water demand models, as tested through the sensitivity analysis, indicate that water demands could be 10 percent higher or 10 percent lower than assumed. Ten percent of year 2000 demand would be 28,500 acre-feet, and this number would grow over time. As long as the other elements of the demand predictions do not have an upward bias, the safety factor is considered reasonable in this instance.

Increasingly wide oscillations in annual water demand due to weather would also suggest a need for some cushion. Other utilities incorporate the concept of a safety factor by assuming the higher end of a range of demand forecasts or underlying assumptions in their supply planning. A cushion appears to be prudent, and 30,000 acre-feet does not appear unreasonable.

## **Concluding Observations About Denver Water's Demand Forecasts**

The water demand forecasts utilized by Denver Water in its February 2002 IRP consist of four elements:

- The demand forecasting model as utilized to develop treated WSA projections;
- an adjustment for natural replacement;
- an adjustment for fixed and special commitments; and
- a safety factor.

Each of these has been evaluated for its validity and reasonableness as a basis for developing future water development strategies. The demand forecasting model is an appropriate tool for Denver Water, and its reliability should be considered generally sound. The underlying economic and demographic forecasts that drive the water demand forecasting model are as reasonable as such forecasts can be, given their inherent level of uncertainty. The natural replacement adjustment, although correctly calculated, may not be fully necessary in adjusting future water demand projections, giving a conservative bias to the forecasts. Fixed and special commitments to entities outside the Denver Water service area are commitments that must be honored. The safety factor is a prudent water planning tool for water supply planners. In conclusion, the water demand projections produced from the 2002 IRP offer an acceptable basis for water supply planning purposes.

## **Water Conservation**

As part of the IRP, the Denver Board of Water Commissioners set as a water conservation goal a savings of 29,000 acre-feet of water by buildout. The near-term 2030 conservation goal was set at 16,000 acre-feet. These goals appear to be based upon historical conservation savings and a view that, by elevating the focus and importance of conservation, more savings could be achieved through the identification and implementation of more aggressive conservation programs.

It is difficult to quantify savings from many conservation programs. Denver Water estimates that a total of 1,400 acre-feet was conserved between 1996 and 2000, stemming from indoor and outdoor incentive programs and educational measures. Clearly, much more aggressive programs will need to be devised and implemented to come close to achieving the conservation goals for 2030 and buildout.

Historically, Denver Water conservation programs have focused upon education and awareness and, more recently, incentive programs. The education programs have been diverse and extensive, including promotion of xeriscaping, presentations, school programs, publications, articles and mass media campaigns. Denver Water alone has expended approximately \$450,000 per year on educational and awareness programs. These costs do not include conservation campaigns by other water utilities, which are likely to have cumulative effects in the Denver area since media campaigns cross water service area boundaries.

Incentive programs have been a more recent phenomenon. A separate program has been aimed at commercial and industrial customers, residential customers, and parks. A consultant, Maddaus Water Management, was brought in to evaluate Denver Water's conservation programs and to make suggestions. They recommended that incentive programs become much more aggressive and that a combination of new education, rate structure changes and mandates or regulatory measures also be considered.

As part of the IRP process, Denver Water followed up the consultant recommendations with an extensive identification and evaluation process of alternative conservation measures. Three packages of conservation programs were selected from this process that would achieve the desired savings in conservation. After evaluating these three packages, the fourth package, known as "best bets," was devised and adopted as the conservation approach and these were deemed preferable by the Board of Water Commissioners. These conservation measures provide substantial incentives for water savings — \$4,500 per acre-foot of proven savings for all irrigation customers and for commercial and industrial entities. A development plan review was strengthened for building sites over 10 acres. A rebate program will also be devised for installing rainfall sensors, and other minor programs were also adopted.

The potential conservation savings from the current plan is highly uncertain but cannot be considered unrealistic. Historical programs that yielded modest results will be strengthened considerably, suggesting greater savings, but the extent of those savings is unknown. Uncertainties include:

- the effectiveness of the program design;
- water customer response;
- verification of savings; and
- ensuring that conservation savings do not revert back to previous consumption patterns.

The potential for conservation savings was validated by a 1999 telephone survey that indicated that savings from automatic sprinkler systems was clearly possible with more attention and more motivation on the part of customers.

In sum, water savings from conservation can only be achieved through programs that are much more aggressive than those in the past, all the while maintaining current efforts. Even so, future savings are highly uncertain. Conservation goals can be achieved if programs are closely monitored and modified in response to program results. If Denver Water is willing to maintain this flexibility with an eye to the goal of achieving 16,000 acre-feet of water savings by 2030, such goals can be met.

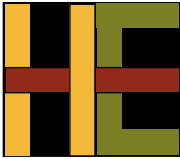
## **Implications and Next Steps**

On the basis of discussions of this review with the Corps and URS, a number of issues are raised which deserve more thorough examination or explanation. These issues should be addressed by Denver Water in its Purpose and Need statement. Based upon the Corps' review of the purpose and need document, it may be determined that additional analysis is required to clarify the following:

1. The Corps would like to replicate the water demand forecasts. This would entail applying the economic and demographic data to the water demand forecasting models, and deriving the three elements of the projections independently to make sure we arrive at the same numbers. Based upon the results of this replication, we reserve the option to look further into the underlying assumptions of the forecasting model and the economic and demographic data which drove it.
2. We will need a clear and complete presentation of the water demand projections on a five year basis, plus the year 2016, through 2030. This information was not found in the IRP and it will be needed in the Purpose and Need statement.
3. We will need to know whether all the distributors in the treated water service area have signed the New Distributor Contracts, and if not which ones have not. It must be clear exactly what are Denver Water's delivery obligations to all of its customers.
4. We will need more verification of the outlook and timing for the fixed contracts and special commitments.
5. We will need more underlying information to validate the calculations of the natural replacement adjustment.
6. More explanation or investigation is needed into the safety factor related to its need, magnitude, and application over time.
7. We would like more information about the specific water conservation techniques that will be undertaken in the future by Denver Water which will provide additional confidence that those savings will be achieved. This might or might not be a component of the Purpose and Need statement

**Appendix A-2**  
**Supplemental Evaluation of Denver Water Demand Projections,**  
**Technical Memorandum,**  
**prepared by Harvey Economics, August 12, 2004**





Harvey Economics ♦ 600 South Cherry Street, Suite 220 ♦ Denver, Colorado 80246  
tel. 720.889.2755 ♦ fax 720.889.2752 ♦ [www.harveyeconomics.com](http://www.harveyeconomics.com) ♦ [he@harveyeconomics.com](mailto:he@harveyeconomics.com)

## **MOFFAT COLLECTION SYSTEM PROJECT EIS TECHNICAL MEMORANDUM**

SUBJECT: SUPPLEMENTAL EVALUATION OF DENVER WATER DEMAND PROJECTIONS

---

DATE: AUGUST 12, 2004

---

PREPARED BY: HARVEY ECONOMICS

---

### **Introduction**

Harvey Economics (HE) prepared this memorandum report in response to a request by the U.S. Army Corps of Engineers (USACE) related to the preparation of the Moffat Collection System EIS. This document describes the results of a supplemental evaluation of Denver Water's demand projections, following an initial evaluation that HE conducted in late 2003 and finalized in early 2004. On the basis of that initial evaluation, Denver Water modified its draft purpose and need statement, producing a revised draft in February 2004. Denver Water finalized their purpose and need (P&N) statement in April 2004 (Purpose and Need Statement for the Moffat Collection System Project, Denver Board of Water Commissioners, April 2004). After reviewing that statement, the USACE had remaining uncertainties about certain aspects of the demand forecasts. In late April 2004, HE received formal approval to proceed with this supplemental evaluation.

The supplemental evaluation consisted of these tasks:

- HE obtained the models and other information with which to replicate Denver Water's demand projections. This task included re-running Denver's water demand model and identifying and replicating adjustments Denver Water made to water demand projections.
- HE performed a detailed review of the natural replacement adjustment and calculations.
- Denver Water's assumed 30,000 acre-foot safety factor was examined as to origin and justification.
- HE reviewed Denver Regional Council of Governments (DRCOG) economic and demographic projections and methodology for 2004 and compared those to the year 2000 projections that were the basis of the water demand projections in the April 2004 purpose and need statement.

The overall purpose of this supplemental evaluation was to determine whether the water demand projections in Denver Water's April 2004 purpose and need document could be relied upon in the preparation of the Moffat Collection System EIS. This supplemental evaluation follows an initial evaluation completed in February 2004 which also focused on

the validity of Denver Water's demand projections set forth in its April 2004 document, but which were drawn from its 2002 IRP process. HE concluded in this initial evaluation that the IRP demand forecasts were reasonable and acceptable by the standards of this practice with these supporting observations:

1. Denver Water's treated water demand model was sophisticated, state-of-the-art and appropriate for application in this case.
2. The data sources for the model were appropriate and acceptable.
3. Statistical measures of validity, backcasting and sensitivity analysis all showed the model to be acceptable.
4. DRCOG's methodology and assumptions and spatial attributions were appropriate and reasonable, and BBC's extrapolation of the forecasts was acceptable.
5. The natural replacement adjustment seemed reasonable, though it could be an inaccurate reduction of forecasted demand if it had already been captured in the demand model.
6. It was reasonable to assume that all special contracts will need to be supplied by 2030.
7. The 30,000 acre-foot safety factor seemed reasonable.
8. New conservation savings of 16,000 acre-feet by 2030 were not unrealistic.

Uncertainties about the demand forecasts remained, however, including questions of replicability of the forecasts, the assumptions and methodology of the natural replacement adjustment, the basis for the safety factor, and the potential changes in economic and demographic projections for the Denver area.

HE examined only those elements of the water demand projections for which the USACE requested evaluation based on HE's initial assessment and with HE's concurrence. Further, the information provided by Denver Water was represented and accepted without an audit of the original data sources. HE found the model overall to be reasonable and capable of producing reasonable results. Since it was not deemed necessary, HE specifically excluded an evaluation of historical data that went into model construction, the regression analyses, and the specification of the model itself.

In this memo, HE has not attempted to prepare new water demand projections for the Denver service area based on updated information or suggested modifications. We confined our evaluation to the usefulness of the Denver Water demand projections for the purpose of the EIS.

## **Replication of Water Demand Projections**

The April 2004 P&N statement provided water demand projections in Section 5, based in large part upon Denver Water's Integrated Resource Plan (IRP) published in February 2002. HE attempted to reproduce those water demands by applying the models, equations, data sources and adjustments that Denver Water utilized to arrive at the demand projections in the P&N statement. HE's replication efforts and results are summarized below.

**Overview of demand projections.** The Denver Water projections cover the time period from 2000 to the year 2050, with an emphasis on the year 2030 for the purposes of the Moffat System EIS. Although water demand projections are depicted in the IRP and in the purpose and need statement as continuous annual figures for graphic purposes, the projections themselves focus on decades only during this time period. The demand projections are computed as a series of discreet components described in the IRP and combined to arrive at total demand, as illustrated in Exhibit 1.

**Exhibit 1.**  
**Components of Denver Water's Demand Projections, 2001.**

Denver Water's Demand Projections (Thousands of acre-feet)*	
	2000 (actual)      2030
Total Treated Water Demand from Model	249      339
+	
Fixed and Special Contracts	43      61
-	
Natural Replacement, 2000 to 2030	0      24
↓	
Initial Demand	292      376
+	
1999 Arvada Contract	0      3
+	
Safety Factor	30      30
↓	
Final Demand	322      409

\* Rounded to the nearest 1,000 acre-feet.

Source: Denver Water, *Integrated Resource Plan*, Demand Appendix, Table I-1, February 2002, and, *Purpose and Need Statement for Moffat Collection System Project*, Denver Board of Water Commissioners April 2004, and Denver Water (John Loughry) working papers, 2001.

Treated water demands include those water supplies that are delivered to end use customers within the Denver Service Area, plus a six percent system loss. Fixed and special contracts are a set of water delivery agreements between Denver Water and a number of other water suppliers and users beyond Denver Water's traditional treated water customer groups within its service area. Natural replacement refers to the inevitable replacement of water consuming fixtures and appliances with low water using alternatives. Unlike conservation programs, this natural replacement occurs because water using fixtures wear out or buildings are remodeled,

and only low water using alternatives are available for replacement. The safety factor is an amount of water that the Denver Board of Water Commissioners has determined is needed to make sure that sufficient water will be delivered, given the uncertainty of future water supply and demand assumptions.

The water demand components, and even certain figures presented in Exhibit 1, appear to be inconsistent with Table 3 of the P&N statement, but they are not. First, the P&N statement defines unconstrained demand as treated water demand without conservation. The P&N statement also combines treated water demand and fixed and special contracts. Therefore, the equivalency between Exhibit 1 and Table 3 in the P&N is:

$$\begin{aligned} &\text{Total treated water demand} + \text{fixed and special contracts} = \\ &\text{Unconstrained demand} - \text{conservations savings since 1980} \end{aligned}$$

One final comment must be made regarding year 2000 differences. The P&N statement normalizes treated water demand in 2000 for average weather, whereas Exhibit 1 depicts year 2000 actual treated water demand. HE has chosen to base this evaluation upon the Exhibit 1 figures since these are the actual water demand forecasting components and figures that were developed for the IRP, which then were adjusted and incorporated into the P&N statement. This seeming inconsistency is not, in fact, inconsistent and does not affect the validity of the demand projections in the P&N statement.

**Treated water demands.** Treated water demand, comprised of residential, commercial, industrial and public use, represents almost three quarters of year 2030 demand. A discussion of how treated water demands are calculated and a replication of those calculations is provided below. Denver Water's treated water demands are projected on the basis of a series of models and certain demographic and economic variables that are used to drive those models. The series of models or sub-models that comprise the overall water demand model include: a model of single family water use per household; a model that addresses commercial, industrial and multi-family water use together; and a model that estimates government or public water use.<sup>1</sup> BBC Research and Consulting (BBC) developed these models; the model equations are provided in Exhibit 2.

---

<sup>1</sup> Attachment 4 of the 2002 IRP Demand Appendix provides a comprehensive description of the origins of these models.

## Exhibit 2. Denver Water's Treated Water Demand Models<sup>2</sup>

$$(1)$$

$$\text{Single Family Use} = 186 + 1.78 * \text{Household Income} - 6.06 * \text{Household Density} \\ - 2.170 * \text{Natural Precipitation} + 22.1 * \text{Persons per Household} - 76.1 * \text{Percentage Metered} \\ - 9.42 * (\text{Single Family}) \text{ Marginal Price} - .022 * 3 \text{ Year Average Conservation Expenditure}$$

$$(2)$$

$$\text{Commercial/Industrial/Multifamily Use} = 337 - 7.59 * \text{Natural Precipitation} \\ + 7.3 * \text{Multifamily Households} + 33.5 * \text{Employment}$$

$$(3)$$

$$\text{Governmental Use} = 1,303.7 - 61.6 * \text{Natural Precipitation} \\ - 702.1 * \text{Marginal Price (gov/inst)} + 9.07 * \text{Employment}$$

Source: 2002 IRP Demand Appendix, Attachment 4.

These equations are the result of an extensive statistical analysis completed by BBC. Any evaluation of the methodology or data used to estimate these models was beyond the intended scope of this memo.

In order to forecast treated water demand, projections of each independent variable in the equations above were required. Developed by BBC, these projections are provided in Exhibit 3.

## Exhibit 3. Projected Variables for Water Demand Model Application

	2000	2010	2020	2030	2040	2050
Income/household	\$35,000	\$36,425	\$37,909	\$39,453	\$41,060	\$42,732
Housing units/acre	2.84	2.98	3.12	3.27	3.41	3.55
Inches precipitation (May – October)	9.4	9.4	9.4	9.4	9.4	9.4
Population per household	2.35	2.35	2.32	2.31	2.30	2.30
Percent of customers metered		1.00	1.00	1.00	1.00	
Marginal price, single family customers	\$0.99	\$1.12	\$1.23	\$1.36	\$1.50	\$1.66
Marginal price, governmental customers	\$0.72	\$0.91	\$1.01	\$1.11	\$1.23	\$1.36
Annual conservation expenditures	\$1,116,000	\$1,116,000	\$1,116,000	\$1,116,000	\$1,116,000	\$1,116,000
Single family households	244,199	272,814	309,358	331,203	356,069	378,990
Multi family households	199,793	223,211	253,111	293,709	335,327	378,990
Persons employed	802,019	886,644	981,188	1,068,599	1,161,547	1,250,666
Population	1,043,652	1,165,658	1,303,524	1,443,546	1,590,213	1,743,353

Source: Denver Water (John Loughry) worksheet, *Historic Data for Service Area – X*.

<sup>2</sup> Note that due to rounding these differ slightly from those used and presented in the BBC appendix beginning on page 11.

The basis for projecting each of the variables in Exhibit 3 is described in the 2002 IRP Demand Appendix and in the internal spreadsheets and information provided by Denver Water and BBC. The sources of information for developing the projections in Exhibit 3 include historical information from the U.S. Department of Commerce, the U.S. Census Bureau and DRCOG. Long-term, normalized precipitation is assumed, as is a continuation of 100-percent metering and a constant dollar level of conservation expenditures in 1983 dollars such that future conservation programs could be analyzed separately in the P&N document. Increases in marginal price stem from policy assumptions provided by the Director of Finance at Denver Water. We assume these variable projections to be reasonable; further evaluation of these projections was beyond the HE work scope. Numbers of single family and multi-family households, employment and population, are derived from DRCOG forecasts allocated to the Denver Water service area. These demographic variables exert a major influence on Denver Water's demand projections.

The water demand projections begin with the application of each variable for a given time period to each model. These results are then adjusted upward by five percent, an *ex poste* adjustment to correct for systematic model error. That is, from 1985 through the year 2000, backcasts of the water demand model under-predicted water demand by an average of almost five percent. To correct for this bias, five percent is added to the aggregated models' predicted results.

HE replicated each of the calculations for single family water use, applied the appropriate variable projections to the single family water use model to derive demand projections, and then adjusted projections upward by five percent. Next, HE applied the single family household projections to the modeled water use per household to develop overall, single family, treated water demand projections. For the second treated water use component, consisting of commercial, industrial and multi-family use, HE performed a similar exercise, wherein the appropriate variables were applied to this model and those results were adjusted upward by five percent. A similar exercise was performed with the government sub-model to produce government water use projections for the Denver service area. A comparison of the HE results with the Denver Water results is provided in Exhibit 4.

**Exhibit 4.**

**Comparison of Denver Water's Treated Water Demand Projections with Harvey Economics Replication, 2000 to 2050, in Thousands of Acre-Feet**

		Commercial / Industrial /			
Year		Single Family	Multi-Family	Government	Total
2000	Denver Water	126.76	101.58	20.86	249.20
	HE Replication	126.76	101.58	20.86	249.20
2010	Denver Water	143.49	108.32	27.86	279.67
	HE Replication	143.49	108.32	27.86	279.67
2020	Denver Water	162.74	119.92	30.56	313.22
	HE Replication	162.74	119.92	30.56	313.22
2030	Denver Water	174.80	130.98	33.04	338.82
	HE Replication	174.80	130.98	33.04	338.82
2040	Denver Water	188.49	142.69	35.64	366.82
	HE Replication	188.49	142.69	35.64	366.82
2050	Denver Water	201.41	154.02	38.10	393.53
	HE Replication	201.41	154.02	38.10	393.53

Source: Denver Water (John Loughry) worksheets and Harvey Economics.

Year 2000 figures represent actual water use. HE was able to replicate exactly Denver Water's treated water demand projections as utilized in the April 2004 P&N statement.

**Fixed and special contracts.** Over past years, Denver Water has entered into raw water and treated water contracts with municipal, industrial and other water users. According to the P&N statement, Denver Water has approximately 20 contracts with various Colorado water suppliers to deliver raw, recycled or treated water, amounting to a total of 61,500 acre-feet in total future obligations. As of 2000, these customers were receiving approximately 43,000 acre-feet of water, and their calls for additional supplies under their contracts with Denver Water are accelerating more quickly than Denver anticipated.<sup>3</sup>

Denver Water performed a straight-line interpolation from 2000 to 2030 as the assumed deliveries it will make under the fixed and special contracts. The assumed date of maximum delivery for each contractor was based upon conversations by Denver Water staff with each of the local providers, although the fixed and special contract customers are under no obligation to provide Denver Water with firm projections of water use or of when the maximum deliveries will be required. Each provider can utilize Denver Water's supplies based upon the availability and cost of other water resources compared with their individual demand patterns. Under these circumstances, the assumed maximum obligation of 61,000 acre-feet and the interpolation to current use is reasonable.

<sup>3</sup> John Loughry, Denver Water, 2004.

**Natural replacement.** Natural replacement is calculated for residential, commercial, industrial and governmental water users, although natural replacement savings in the residential sector are used to develop commercial, industrial and governmental savings. Residential natural replacement stems from the replacement of larger volume toilets with lower gallonage models, low flow showerheads, and low flow faucets. Clothes washers were not considered as part of natural replacement but instead are examined under conservation assumptions, presumably due to consumer's continuing choice among clothes washers with different water volumes and technologies.

The data sources for the natural replacement savings include research conducted during the Denver Systemwide EIS, Bill Maddaus Consultants, the American Water Works Association Research Foundation report entitled, *Residential End Uses of Water*, and BBC's projections of households, persons per household, and water demand projections for single family, multi-family, commercial and institutional consumers. These data sources are appropriate for developing the assumptions necessary in projecting natural replacement savings.

Denver Water calculated natural replacement savings in two spreadsheets, one entitled "NR8DZP.wk4" and "NRSUM5X.xls." The calculation of natural replacement water savings relies upon an extensive set of calculations and assumptions further discussed in the next section of this memorandum. The bulk of residential water savings are expected to come from a replacement of toilets as they wear out or as the remodeling of older homes occurs. In essence, the computation requires an assumption of the average number of gallons per flush weighted across households multiplied by the number of flushes expected to occur per day. HE has replicated Denver Water's calculations for natural replacement savings and, using all of Denver Water's assumptions, has come up with the same level of savings that Denver Water projected. However, certain Denver Water calculations and assumptions were found to be unsupportable, and these are discussed detail in the next section of the memorandum.

**Arvada contract.** Beyond the fixed and special contract customers, Denver Water has a contract with the City of Arvada to provide 3,000 acre-feet of firm yield if Denver eliminates its Moffat Collection System constraints. Since Arvada's additional 3,000 acre-feet obligation will accrue to Denver if the proposed Moffat System improvements go forward, it must be assumed as an additional demand.

**Safety factor.** Denver Water assumed a 30,000 acre-foot safety factor as part of its current planning for future supply. This number was not calculated but assumed, based upon 10 percent of total Denver Water system firm annual yield that existed in the early 1980s at the time of the Systemwide EIS. The 30,000 acre-foot calculation was correct at that time.

**Summary of HE demand projection replication.** HE located and interpreted the original source documents that provided the calculations for Denver Water's demand projections as provided in the April 2004 P&N statement for the Moffat Collection System Project. HE replicated the calculations for each component of the water demand projections based upon the sources that were provided. HE was able to replicate exactly the water demand projections provided in the sources.

## Further Examination of Natural Replacement Adjustment

HE examined the computationally complex natural replacement adjustment in detail to ascertain the validity of the figures assumed in the 2004 P&N statement. The evaluation of each component of the natural replacement adjustment is described below.

**Residential toilets.** Water savings from the natural replacement of toilets in residences is the largest element of savings likely to be generated from natural replacement. The savings occur because when toilets wear out or are replaced due to remodeling, the only toilets available for such replacement have lower water volumes in the tank compared with the replaced model. For example, at the time of the Systemwide EIS in 1982, more than 268,000 out of a total 327,000 households had 5.5 gallon toilets. However, if one of those toilets were to be replaced in 2004, only 3.5 gallon or 1.6 gallon toilets would be available. Similarly, 3.5 gallon toilets purchased in the 1990s will eventually be replaced, in part, by 1.6 gallon toilets. If the number of households with each toilet size can be estimated for current conditions and projected into the future, the calculation of weighted average gallons per toilet flush for the Denver service area may be derived. The weighted average gallons required per toilet flush is calculated by Denver Water based on the following equation:

$$\text{Average gallons per toilet flush} = \frac{hh_1 (5.5) + hh_2 (5.32) + hh_3 (3.5) + hh_4 (1.6)}{\sum hh_{1-4}}$$

where:  $hh_1$  = Number of households with 5.5 gallon toilets  
 $hh_2$  = Number of households with 5.32 gallon toilets  
 $hh_3$  = Number of households with 3.5 gallon toilets  
 $hh_4$  = Number of households with 1.6 gallon toilets

This calculation relied upon household estimates for each category from 1980, 1982, 1990, 2000 and projections for 2020 and 2050. Data sources for these households include the U.S. Census Bureau, the Systemwide EIS and BBC projections. The stock of households with various toilet sizes estimated for 1982 is tracked over the ensuing years as toilets are replaced, moving households from the 5.5 gallon size to the 5.32 gallon size to the 3.5, and eventually, to the 1.6 gallon toilet. During the forecast period, additional toilets were added based upon the size of toilet available at that time, and this cascading effect toward smaller volume toilets begins with those households. Conceptually, this approach is logical, and the data sources for the assumptions behind this analysis are reasonable.

However, computational inconsistency occurred as the toilets are replaced over time. Denver Water attempted to use a 3 percent per year conversion of 5.5 gallon toilets to the smaller size of 3.5 gallons, and a similar percent for the cascading effect of all smaller sized toilets. There are two ways to perform this calculation correctly: (1) Calculate a 3 percent per year conversion rate from the toilets in the original time period and carry that 3 percent absolute number forward until all of the toilets are converted; or (2) calculate a 3 percent conversion on a declining base of remaining, unconverted households, which would result in a

conversion of households that is slower. Denver Water did not perform the calculations in either of these ways, but rather mixed the two approaches. HE believes that the most logical rationale for a 3 percent replacement rate is a full replacement of the old toilet stock in 33 years. Therefore, we recommend that this adjustment in the calculations be made.

The second part of the natural replacement of residential toilets calculation applied the weighted average gallons per flush times the number of households in the Denver service area times the persons per household times the number of flushes per person per day. To the number of flushes per day, Denver Water added a 10 percent adjustment in the number of flushes for double flushing to account for a perceived need for more water flow with the lower gallonage toilets. This equation looks as follows.

$$\begin{array}{lcl} \text{Residential water demand} & = & \text{weighted average toilet volume} * \\ \text{from toilets} & & \text{number of households} * \text{persons per household} * \\ & & (5.1 \text{ flushes per person per day} + 0.51 \text{ flushes,} \\ & & \text{double flushing factor}) \end{array}$$

Next, Denver Water calculates what the residential toilet demand would have been in the future, i.e. 2020 or 2050, compared with the weighted average toilet volumes that existed in the year 2000. That is, if the predominate toilet size was 5.5 gallons instead of the reduced volume in the calculation shown in the equation above, residential water demand would have been, of course, higher. Therefore, residential toilet demand in the year 2000 less residential toilet demand in the year 2020 indicates the natural replacement savings from residential toilets for the year 2020. Next, Denver Water makes an additional adjustment in the number of flushes as a correction for the diminishing functionality of low flow toilets or deterioration over time. Thus, in years 2020 and 2050, Denver Water assumes 6.1 flushes per person per day instead of 5.61 flushes assumed for the year 2000. The manner in which Denver Water calculates this assumption results in an apparent increase instead of decrease in water savings, suggesting that the adjustment was not implemented correctly. The correct way to calculate Denver Water's assumption is to reduce the natural replacement savings from residential toilets by 10 percent, or to increase the flushes per day for the year 2000 when making the comparison to 2020 in calculating the savings. This change reflects Denver Water's view that ultra-low flow toilets lose their water efficiency over time as parts are replaced reducing natural replacement savings.

**Natural replacement of showers.** The computation is based upon a conversion of showerheads delivering 3.8 gallons per minute to showerheads that deliver 2.5 gallons per minute saving 1.3 gallons per minute per showerhead. Denver Water assumes that showerheads will be replaced at the rate of 5 percent per year. HE found these assumptions and calculations to be appropriate.

**Residential faucets.** Similar to showers, Denver Water assumed that 5 percent of residential faucets will be replaced by 1.37 gallon-per-minute faucets. This produces an estimate that 5 percent of faucet flows will be saved by 2020. HE also found these calculations and assumptions to be appropriate.

**Natural replacement savings from commercial, industrial and institutional consumer sectors.**

First, Denver Water estimated commercial, industrial and governmental water demand in aggregate and extracted multi-family use. Denver Water calculated the proportionate total water use from those sectors that are subject to natural resource savings, i.e. demand from toilets, showers and faucets. Finally, Denver Water assumed that the relative savings from these end uses in the residential sector will be the same in the commercial, industrial and governmental sectors scaled to the proportionate end use of the commercial, industrial and governmental sectors. On the whole, this methodology and the data sources that support it are sound in HE's opinion. It is noted however, that the recommended changes to the calculation of natural replacement toilet savings will also affect commercial, industrial and institutional savings because of the linked calculations.

**Natural replacement summary.** The exhibit below points out the natural replacement savings calculated by Denver Water and the changes recommended by HE.

**Exhibit 5.**

**Projected Natural Replacement Savings, Acre-feet in 2020 and 2050.**

	2020			2050		
	Denver Water	HE	Difference	Denver Water	HE	Difference
Residential						
Toilets	13,600	12,300	1,300	24,500	18,400	6,100
Showers	2,800	2,800	0	2,800	2,800	0
Faucets	700	700	0	700	700	0
Commercial/ Industrial/ Governmental	4,900	4,400	500	9,200	6,900	2,300
<b>Total Savings</b>	<b>22,000</b>	<b>20,200</b>	<b>1,800</b>	<b>37,200</b>	<b>28,800</b>	<b>8,400</b>

Source: Denver Water (John Loughry) spreadsheets and Harvey Economics.

Note: The P&N statement indicates 39,000 acre-feet of natural replacement savings by 2050, which includes the six percent system loss adjustment that Denver Water made to all demand forecasts. That adjustment was not a part of the natural replacement calculations evaluated in the above exhibit.

Note: This exhibit shows natural replacement savings for 2020, not for 2030 as the other elements of the demand forecasts show. Denver Water's calculations of natural replacement savings were for 2020 and 2050 and did not forecast specifically for 2030. In the IRP and the P & N statement, Denver Water actually interpolated from 2000 to 2050 for the decade projections in between. Since Denver Water based its evaluation on two benchmarks, 2020 and 2050, HE recommends using those for interpolation purposes. An interpolation of natural replacement savings to 2030 would be roughly 27,000 acre-feet for Denver Water (instead of 24,000 acre-feet based on the original interpolation as shown in Exhibit 1) and 23,000 acre-feet for HE, with a difference of 4,000 acre-feet.

On the basis of our evaluation, we recommend a modified estimate of natural replacement savings of 20,200 acre-feet by the year 2020, a decrease of 1,800 acre-feet in savings, compared with Denver Water's projections. For the year 2050, HE recommends projected natural replacement savings of 28,800 acre-feet, a decrease of 8,400 acre-feet in savings compared with Denver Water projections.

## Safety Factor

As part of its water demand projections, Denver Water assumed a safety factor on top of identified sources of future demand as insurance against an uncertain future. Originally, the safety factor was devised to ensure against discontinuities in supply at the time of the Denver Systemwide EIS process in the early 1980s. Faced with an identification of system risks (e.g., collapse of a trans-mountain tunnel), the Denver Board of Water Commissioners adopted a 30,000 acre-foot safety factor, which was 10 percent of safe annual yield calculated at that time.

The USACE asked HE to evaluate further this safety factor focusing on two questions. Is this safety factor really justified? If so, what is the appropriate basis or level of such a safety factor? HE has not performed an extensive analysis of safety factors or precise estimates of what the correct safety factor is, but we have identified reasonable approaches to arriving at such a safety factor and what the implications of those numbers might be.

**Justification.** The need for a safety factor for any water utility should be based upon two conflicting considerations: an objective recognition of the risks and uncertainties that the utility faces, tempered by the costs of carrying such a safety factor upon the customer base, the environmental costs and the opportunity cost of reserving that supply as a form of insurance policy. The risks that Denver Water faces are real; HE notes distinct types of risk related to either the supply or the demand side of water utility planning:

- unexpected impairment of supply facilities or components;
- legal or institutional actions that subordinate or otherwise reduce water rights;
- unexpected delays in system development, including permitting or construction; and
- variations in demand forecasting model parameters and unexpected changes in future population or employment.

Within these categories of risk, it is not difficult to conjure up scenarios that result in a shortage of water compared with a full acceptance of supply and demand assumptions that can be identified at the present moment. It must be remembered, though, that assumptions about future water supplies and demand represent the best estimates that qualified professionals predict, and that such predictions have a probability of being too high as well as too low. Perhaps the only certainty is that they will not be absolutely correct.

The cost of eliminating all risk to Denver Water or any utility would be excessive. Unused water system capacity and infrastructure has a cost that must be borne by water users faced with an unforeseen water shortage for whatever reason. Some, though not all, customers have an ability to reduce water use, albeit suffering economic or other impacts as a result. However, water users would be unlikely to pay more for the insurance policy of an excessive safety factor if those costs exceeded the economic or other impacts they might undergo from

the shortage. This presumes, of course, that the utility makes every effort to correct the problem or eliminate the shortage as soon as possible.

In sum, HE finds the concept of a safety factor to be sound as long as it is not excessive. Other utilities, such those cited by Denver Water in its P&N statement further support such a concept. Denver Water is obligated to meet the needs of customers in its service area, and it would be imprudent to ignore the risks associated with water supplies or demands that might keep Denver Water from accomplishing its mission.

**Safety factor level.** For the purposes of this brief safety factor evaluation, HE considered three methods of quantifying the safety factor for Denver Water. These or other methods should be considered since any safety factor should have a supportable basis.

**Ten percent.** One approach would be to simply update the calculation of 10 percent of existing firm annual yield of the Denver Water system. This method would be consistent with the genesis of Denver Board of Water Commissioner policy. As of 2003, the total Denver Water system firm annual yield was 345,000 acre-feet and this is expected to grow to 375,000 acre-feet. Thus, a 10 percent safety factor using this approach would be 34,500 acre-feet as of 2002, growing to 37,500 acre-feet by 2030.

**Ten-year supply.** Another logical approach to establishing a safety factor is to assume that a water utility must have water supplies sufficient today to meet demand ten years into the future. Ten years might be related to the time required for planning, permitting, financing and constructing a water supply project in the twenty-first century. Based upon Denver Water's decennial water demand projections, this technique would suggest that the year 2000 supplies would need to meet year 2010 demand and year 2030 supplies would need to meet 2040 demand. One way of implementing this safety factor is to calculate the difference in demand ten years in the future. In year 2000, the required safety factor would be 38,000 acre-feet, but this safety factor would decline to 23,000 acre-feet by 2030. Three potential disadvantages of this technique might be the variability of the safety factor over time, the uncertainty of supplies and future expansions, and this safety factor's dependence upon the water demand projections that are themselves uncertain.

**Standard deviation.** An alternative to the approaches discussed above is one that attempts to measure the variability between actual use and the predictions made by the models used to generate demands. For this approach, confidence intervals are used to establish upper and lower bounds using past data to develop estimates of the probability of error associated with predicting total demand.

While the analysis is limited to only modeled demand (excluding fixed and special contracts or natural replacement) it does provide a useful and commonly used tool for calculating additional needs attributable to historical uncertainties associated with demand.

One might be confused by the similarities between this approach and the five percent adjustment to correct for bias in the demand model. It is important to note that these are

completely unrelated. The adjustment made to correct for historically observed model bias attempts to improve the chances that model forecasts are correct on average. Even if the model produced forecasts which were correct on average, 50 percent of the time actual use would be below the prediction and 50 percent of the time it would be above.

Confidence intervals, on the other hand, provide a range of projections around the average. This range identifies the set of values that are likely to occur with a given probability. Commonly used confidence intervals among water utilities are 95 and 99 percent. For example, a confidence interval of 99 percent means that 1 out of every 100 years, we would expect levels of demand outside of the range identified.

This safety factor, intended to account for only the uncertainty associated with demand, suggests the need for an additional 20,500 to 27,600 acre feet of margin by 2030 depending on the confidence interval selected. Again, it is important to note that this figure does not account for uncertainty related to other demand sources, catastrophic losses of system facilities, delays in the permitting or construction of future additions to the system, or increased stream flow requirements for endangered species.

**Safety factor summary.** The safety factor for Denver Water is justified. The amount of that safety factor should be based upon a reasonable or logical approach that does not produce an excessive amount. Three possible approaches have been identified, and two of these suggest that the 30,000 acre-feet safety factor might be low.

## **Denver Regional Council of Government (DRCOG) Economic and Demographic Projections**

Water demand projections for the Denver area are driven largely by changes in economic and demographic activity, especially growth in population, households and employment. The original source of these projections is DRCOG, an agency made up of local governments in the Denver metropolitan area. This agency prepares population, household and employment forecasts, primarily for transportation planning under contract to the Colorado Department of Transportation and the Federal Highway Administration.

Many organizations utilize DRCOG forecasts in their planning processes. Federal governmental entities that use these projections include the US Postal Service, the Federal highway and transit authorities, the US Environmental Protection Agency and the USACE. State government departments that rely on DRCOG forecasts include the Colorado Department of Health and Environment, Department of Local Affairs, Department of Human Services and the Colorado Legislative Council. Local governmental entities include school districts and cities and counties in the DRCOG region, water and wastewater districts in the region and the Regional Transportation District.

Private enterprises that rely on DRCOG projections include Kohl's Department Store, the May Company, the Dayton Hudson Corporation, Kroger Foods, Safeway Foods, healthcare companies such as Kaiser Permanente, commercial development and real estate firms and

private consulting firms for highway, transit, environmental, retail and commercial development.

The State of Colorado reconciles its projections with DRCOG to eliminate inconsistencies. Although private projections are known to exist, it is believed that DRCOG is the predominant source for projections of population and employment for the Denver metropolitan area.

HE's evaluation of the DRCOG projections focused on changes in methodology and numerical projections of population, households and employment in the Denver area.

**DRCOG forecasting methodology.** HE reviewed the DRCOG forecasting methodology utilized in the year 2000 and compared it to the methodology used in 2004. The year 2000 DRCOG forecasts were implemented in Denver Water's demand forecasts found in the 2002 IRP. The objective was to determine if the forecasting methodology was sound and whether it has changed as of early 2004.

In 1999, DRCOG approved the economic and demographic forecasting methodology that its Economic Forecasting Task Force (Task Force) developed at the regional level for the Denver metro region. The Task Force created the Regional Socioeconomics Model from which they generated forecasts of population, households and employment by major industry for the Denver metro region. The results of this model served as the major driver behind the subsequent economic and demographic forecasts that Denver Water incorporated into its water demand projections in the IRP.

To create the Regional Socioeconomics Model, DRCOG and its Task Force relied upon its members — planners, economists and representatives from industry and local and state governments — to provide or gather land development and planning information from virtually every community in the Denver metro region and to combine it with base data from the U.S. Census Bureau's 1990 census to develop assumptions about socioeconomic trends in the Denver metro region. The Task Force created these forecasts at two levels, regional and small areas or Transportation Analysis Zones (TAZs).

**Regional forecasts.** The Task Force developed regional population, household and employment projections based on analysis of macroeconomic trends at the national, state, regional and local levels. The Task Force began with a socioeconomic forecasting model from the State of Colorado's Center for Business and Economic Forecasting (CBEF) that considered national economic projections from Standard and Poor's DRI model and adopted several assumptions from these forecasts, including:

- Smooth full employment growth path at the national and international levels without any major exogenous shocks
- Use of the U.S. Census Bureau's middle-growth population forecast with no major disruptions

CBEF then developed assumptions about state economic growth patterns from these national and international economic trends to project future employment in the state. The State then combined CBEF's economic model with the State demographer's demographic model that uses cohort growth analysis to project the state's future population. The State compared its demographic projections of population with its economic predictions of population through labor force participation rates and finalized its forecasts of population and employment. At the state level, the Task Force adopted some important assumptions associated with these State forecasts, including that Colorado and Denver will continue to benefit from relative advantages in cost of living and attractiveness that will create higher than national average growth rates in population and employment.

The Task Force then combined these international, national and state assumptions and macroeconomic trends with local land development information and characteristics of small development areas in the region to create the Regional Socioeconomic Model. The model incorporated additional local assumptions, including:

- Household formation will continue to follow national patterns;
- Labor participation rate will fall as the population ages but will remain higher than the US rate;
- No predicted business cycles, since projections are normalized;
- Continuing availability of adequate supply and quality of utilities;
- Denver metro region can grow significantly without a large increase in average time traveled;
- No major changes in governmental fiscal measures or regional growth control mandates; and
- Stable military employment.

The end result of the model was regional forecasts of population, housing and employment that DRCOG then stepped down to the TAZ level for more practical local planning purposes.

**Small area projections.** After developing the Regional Socioeconomic Model to project population, employment and households in the DRCOG region, the Task Force then apportioned these projections to some 1,500 Transportation Analysis Zones (TAZs), which are roughly 1/3 the size of U.S. Census Bureau tracts. To make this apportionment, the Task Force was guided by the Mile High Compact (MetroVision 2020) that most cities and counties in the DRCOG region signed in 2000. The compact calls for a combination of compact city, satellite centers and corridor development techniques to create a 10 percent higher urban density in the metro area by 2020.

The Task Force began this stepdown of their regional forecasts with subarea growth projections for broad areas of the DRCOG region, including urban areas and more rural areas that have different growth characteristics. The Task Force then further distributed growth within subareas to the 1,500 TAZs using an attractiveness index that measured each area's growth potential with factors such as availability of undeveloped land, attractiveness of transit choices and proximity to urban centers. The higher the zonal attractiveness index, the more quickly DRCOG anticipated that the particular TAZ would grow.

Denver Water utilized these final TAZ level projections and, through GIS analysis, translated them into small area projections for its planning purposes. Denver Water used these projections for forecasting future water demands.

DRCOG's methodology for forecasting population, households and employment in the Denver region has evolved since the 2002 IRP but has not changed dramatically. CBEF now bases its state and regional forecasts on international and national economic trends predicted by <http://www.economy.com>. The Task Force has also contributed new assumptions about growth in the DRCOG region, including:

- Altered labor force participation rates;
- Changes in age, mobility and labor force composition;
- 65 year olds now move away until they are 75 years old (health will improve as wealth increases); and
- Female portion of the labor force will retire in the same pattern as male workers.

The Task Force also changed the boundaries of the area it considered in its economic forecasting, choosing now to consider economic trends in southwest Weld County, Elbert County, Park County and southern Laramie County as influences on the DRCOG region. Broomfield, a Denver area city, has now become a county. The Task Force in 2004 predicts that the DRCOG region will develop from the city center outwards to the urban growth boundary established in the Mile High Compact. As growth reaches the boundary, growth in the center of the city increases, which is important for distribution of growth the TAZs over time.

DRCOG's step-down methods from regional forecasts to TAZs have also been refined since the 2002 IRP. The model now predicts activity in 2,600 TAZs instead of 1,500, and the new zones more closely follow Census tract boundaries. The regional projections still set the limit to growth for the whole area, and the updated step-down approach considers attractiveness of each TAZ, characteristics of each neighborhood and behavior of residents, businesses and employees to distribute that growth throughout the region. The Task Force sets the parametric values for this analysis and creates a 20-variable utility function model that compares available land with residents' and employees' utility or satisfaction with living in each TAZ. Variables include access to mass transit, proximity to urban centers, traffic congestion, economic activity, employment growth, environmental constraints, residential gentrification and other activity, household growth, commute times, median household

income, jobs-housing balance, freeway interchanges, locally planned residential and commercial development, median housing prices and price growth, access to open space, areas influenced by pedestrian access and regional roads, social and cultural amenities, utility access, and vacant developable land. The Task Force also more closely considers the impact of the adopted urban growth boundary in its projections of where growth will occur and when. Local governments can contribute to changes to the inputs of the TAZ projection model, but they cannot explicitly direct the outputs of the model.

**Comparison of 2000 to 2004 DRCOG projections.** HE was able to obtain draft population, household and employment forecasts from DRCOG that were developed in mid-2004. These can be compared to the DRCOG 2000 forecasts to isolate changes that might affect future water demand projections. The DRCOG 2000 and 2004 projections are for the same nine county projection area. Exhibit 5 presents these comparisons for population, households and employment, respectively. The projections reflect actual 2000 figures for the year 2000, HE's interpolations between decades, and BBC's extrapolation from 2020 to 2030 in the year 2000 projections.

**Exhibit 6.****Comparison of DRCOG 2000 to 2004 projections for the Denver Region**

Comparison of DRCOG 2000 to 2004 Projections							
Region							
<u>Year</u>	<u>Population (Number of Persons)</u>						
	<u>2000</u>	<u>2004</u>		<u>Change</u>			
2000	2,333,607	2,414,649	**	3.47%			
2005	2,566,965	2,655,366	***	3.44%			
2010	2,806,794	2,896,083	***	3.18%			
2015	2,998,167	3,136,800		4.62%			
2020	3,225,310	3,382,935	***	4.89%			
2025	3,384,802 *	3,629,069	***	7.22%			
2030	3,552,180 *	3,875,204		9.09%			
	<u>Number of Households</u>				<u>Persons per Household</u>		
	<u>2000</u>	<u>2004</u>		<u>Change</u>	<u>2000</u>	<u>2004</u>	<u>Change</u>
2000	959,900	946,033	**	-1.44%	2.43	2.55	4.99%
2005	1,058,002	1,047,692	***	-0.97%	2.43	2.53	4.46%
2010	1,163,006	1,149,350	***	-1.17%	2.41	2.52	4.41%
2015	1,259,247	1,251,009		-0.65%	2.38	2.51	5.31%
2020	1,351,995	1,355,940	***	0.29%	2.39	2.49	4.58%
2025	1,465,282 *	1,460,872	***	-0.30%	2.31	2.48	7.54%
2030	1,537,740 *	1,565,803		1.82%	2.31	2.47	7.14%
	<u>Number of Employed</u>				<u>Employees per Household</u>		
	<u>2000</u>	<u>2004</u>		<u>Change</u>	<u>2000</u>	<u>2004</u>	<u>Change</u>
2000	1,405,732	1,443,211	**	2.67%	1.46	1.53	4.17%
2005	1,639,202	1,606,151	***	-2.02%	1.55	1.53	-1.05%
2010	1,775,637	1,769,092	***	-0.37%	1.53	1.54	0.82%
2015	1,881,608	1,932,032		2.68%	1.49	1.54	3.36%
2020	1,980,040	2,054,972	***	3.78%	1.46	1.52	3.48%
2025	2,505,633 *	2,177,912	***	-13.08%	1.71	1.49	-12.82%
2030	2,629,536 *	2,300,852		-12.50%	1.71	1.47	-14.07%

Note: \* Projected using BBC assumptions from 2002 IRP.

\*\* Actual 2000 data from US Census Bureau.

\*\*\* Interpolated with 1/3 of growth in each 5 year period.

Source: DRCOG, 2004.

According to DRCOG, Denver area population is likely to grow more rapidly than was anticipated in the year 2000. Not only was year 2000 population higher than expected by almost 3.5 percent, population projections have increased by 9 percent as of the year 2030.

Interestingly, household growth by year 2000 was not as high as DRCOG had anticipated, and future housing growth is projected in year 2004 to be approximately the same as was projected in year 2000. These seemingly contradictory trends are explained by DRCOG's assumption that persons per household, which was 5 percent higher than anticipated in the year 2000, will continue to be higher than was anticipated in the year 2000, and these differences will remain through the projection period. By year 2030, 2004 DRCOG projections call for 1.6 million households in the Denver area, as compared with 1.5 million that were predicted in the year 2000.

The comparison of year 2000 employment projections with year 2004 is erratic. Year 2000 employment was 2.7 percent higher than DRCOG anticipated, but DRCOG anticipates about the same employment in 2010 as it did four years ago in its year 2000 projections. By 2020, the year 2004 employment projections are about 3.8 percent higher than those same projections that were prepared in the year 2000, but longer term employment projections for the year 2030 show DRCOG's 2004 projections 12.5 percent less than the projections developed four years ago for 2030. These erratic comparisons can be explained by a different view of labor force participation rates and the ratio of employees per household. In the year 2000, DRCOG projected an increasing trend in employees per household through 2030. By 2004, DRCOG had assumed a reversal of this trend; that is employees per household would remain stable and then gradually decline as the year 2030 approached.

**Summary of DRCOG changes.** The DRCOG forecasting methodology as represented is sound and widely utilized by local, state and federal planners. Certain methodological refinements and assumptions have occurred with the DRCOG forecasting methodology between year 2000 and year 2004, providing refined information and tools for projection. A comparison of DRCOG's mid-2004 draft projections to its year 2000 projections would suggest higher future population levels, comparable household projections, and employment projections that are generally higher to the year 2020 and then less for the year 2030. Although no formal analysis of the impact of these changes upon Denver Water's demand projections has been made, it is likely that these new projections might have increased slightly water demand projections from 2000 to 2020 and held stable or slightly reduced water demand projections by the year 2030.

## Conclusions

USACE requested that HE conduct a supplemental evaluation of Denver Water's demand projections as provided in its April 2004 P&N statement. This evaluation focused on certain aspects of the Denver Water projections about which USACE was uncertain.

HE obtained, reviewed and replicated all of the calculations that went into the water demand projections prepared by Denver Water. These water demand projections are comprised of five components: treated water demand projections; fixed and special contracts; natural replacement (a deduction from total demand); the 1999 Arvada contract; and the safety factor. HE was able to identify and replicate each calculation.

HE conducted a detailed evaluation of the natural replacement adjustment, based upon worksheets and other unpublished information provided by Denver Water. This examination found several inconsistencies or calculation errors. HE corrected those calculations, which resulted in a net reduction in natural replacement savings, thereby increasing the water demand projections.

HE conducted a further evaluation of the safety factor that Denver Water assumed to be 30,000 acre-feet. Based on interviews with Denver Water personnel, HE found that this figure was based upon 10 percent of system firm annual yield evident in the early 1980s. A

similar calculation today would suggest that the safety factor be 34,500 to 37,500 acre-feet. However, other equally supportable rationales are available to estimate the safety factor. In general, the safety factor for Denver Water is warranted, and an appropriate figure is likely to be at least 30,000 acre-feet.

A review of DRCOG projections developed in mid-2004 indicates a similar methodology as compared with the year 2000, when the IRP was last updated. However, population, households and employment projections have changed, and they are generally flat to higher than those projections were four years ago. This finding would suggest slightly higher water demand projections, although no formal analysis was conducted.

In conclusion, the water demand projections presented by the Denver Board of Water Commissioners in their P&N statement for the Moffat Collection System Project, dated April 2004, are not excessive. It is likely that those water projections, prepared for the 2002 Denver IRP, are understated. Regardless, the water demand projections published in the P&N statement for April 2004 can be utilized in the Moffat Collection System EIS.

## **Appendix A-3**

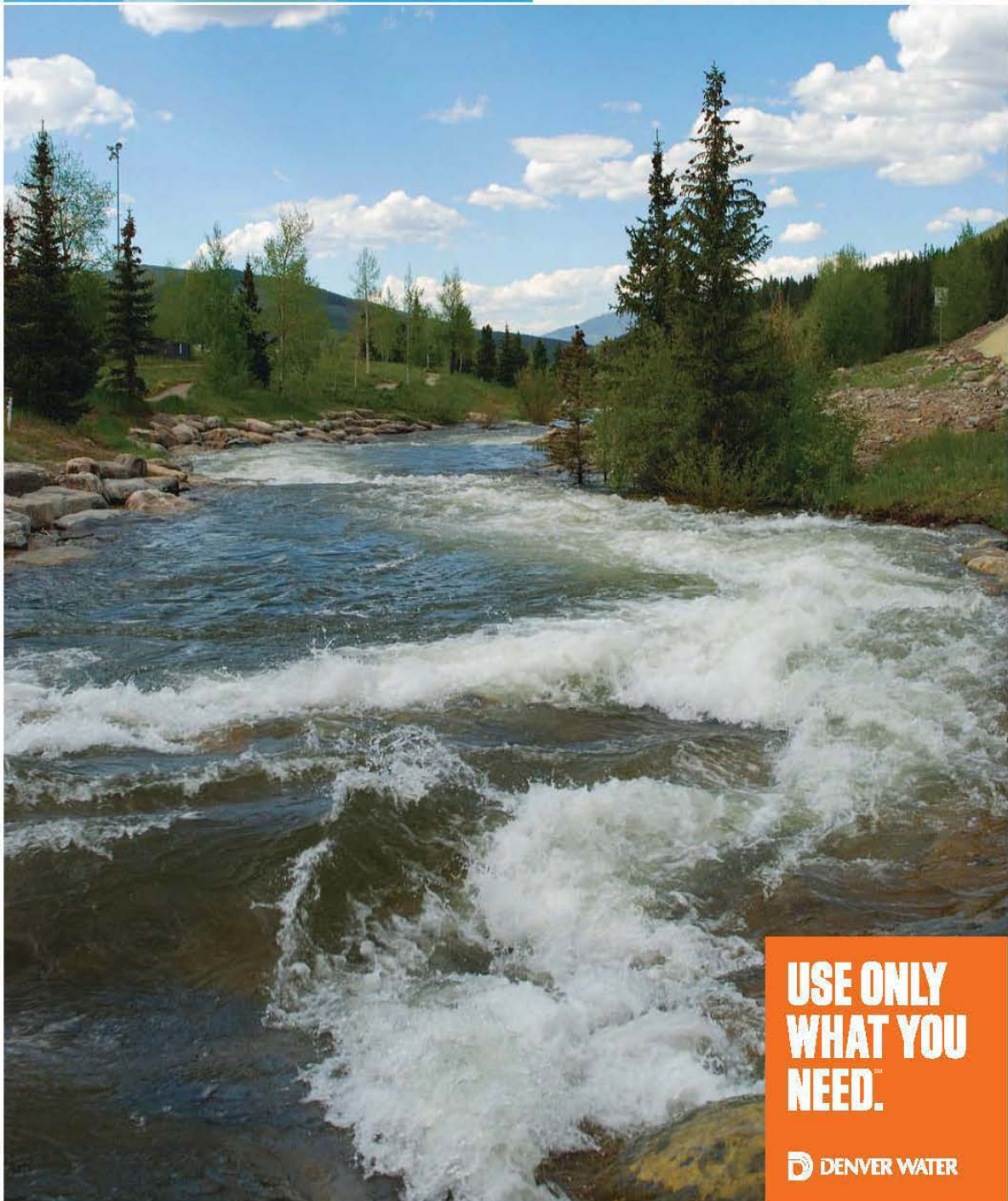
**Solutions: Saving Water for the Future. Information and Contents Regarding  
Conservation and Water Management Techniques.  
A 2011 Denver Water publication**



# SOLUTIONS

2011

SAVING WATER FOR THE FUTURE



**USE ONLY  
WHAT YOU  
NEED.™**

 **DENVER WATER**

## Contents

**02** Using only what they need

**03** Customers lead the way to lower water use

**04** Homeowners association reduces water use by 40 percent

**05** Mile-high water savings

**05** Water savers hit the streets

**06** Summary of Denver Water conservation goals

**07** Master plan sets the path for recycled water's future

**07** Golf course receives recycled water award

**08** Arsenal's lakes and wetlands rely on recycled water

**09** Denver Zoo's new exhibit uses recycled water

**10** Proposed agreement sets the stage for regional cooperation

**11** Regional partnership works to meet future water needs

**12** Front Range Water Council unites water suppliers

**13** Gravel pits find new life

**14** Moffat project looks to minimize impacts

Denver Water recently updated our mission statement to better reflect our commitment to the environment and our community:

*Denver Water will be a responsible steward of the resources, assets and natural environments entrusted to us in order to provide a high-quality water supply, a resilient and reliable system, and excellent customer service.*

One of the ways we're working to achieve this mission is through a diverse plan with a three-pronged approach: conserve, recycle, supply.

Our mission is about much more than just the obligation to our Denver-metro area customers, though. We have a broader obligation to our neighboring communities, to our watersheds, and to the rivers from which we derive our supply.

The future of water in Colorado took a positive step forward this past spring with the announcement of the proposed Colorado River Cooperative Agreement. This unprecedented agreement brings together 35 entities from Grand Junction to the Denver-metro area to work together as partners on a path to responsible water development. The proposed agreement is the largest of its kind in the history of the state, and it sets the stage for changing how Colorado's water resources are managed.

The 2011 issue of *Solutions* highlights some of Denver Water's programs and projects on which we are working to meet supply challenges while maintaining our commitment to managing water in a way that benefits both Denver and the state of Colorado. Our customers continue to prove they are up to the challenge of helping us use water responsibly, and we'll keep providing them with progressive ideas and projects to ensure a secure water future.

Sincerely,



Jim Lochhead  
CEO/Manager, Denver Water



*Solutions* is a magazine published by Denver Water, 1600 W. 12th Ave., Denver, CO 80204; [www.denverwater.org](http://www.denverwater.org)

Writer: Ann Baker, Denver Water, 303-628-6554

Designer: Asher Studio, [www.asherstudio.com](http://www.asherstudio.com)

Editor: Sabrina Hall, Denver Water, 303-628-6324

Printed on Mohawk Navajo 100lb text on 20% post consumer waste

©Copyright 2011 Denver Water

All rights reserved. No part of this document may be reproduced, stored in a retrieval system, photocopied or otherwise dealt with without the prior written permission of Denver Water.

Cover image credits: Blue River in Summit County, ©iStockphoto.com/Linda Mirro

The Use Only What You Need campaign helps visitors to the Belmar shopping center in Lakewood visualize how much water their lawn actually needs versus what people usually give it.

## Using only what they need

Helping customers use only the water they need is one of Denver Water's most important goals. Nearly a decade after one of Colorado's worst droughts, customers are clearly embracing that mission. These days, customers are using 20 percent less water than they were using before the 2002 drought, even though there are 10 percent more of them.

The decline in water use can, in part, be credited to the variety of programs Denver Water offers to encourage conservation. Each summer, Denver Water hires temporary workers to serve as a roving crew of Water Savers. The Water Savers ride bicycles or drive fuel-efficient cars, educating thousands of customers about water waste and enforcing summer watering rules. Denver Water's soil

amendment program, which requires developers to till compost into soil prepped for landscaping, also has been a success. In 2010, staff performed 1,097 soil amendment inspections on more than 5 million square feet of land. Requiring soil amendment on all that land has the potential to reduce those yards' water needs by more than 20 million gallons of water per year.

Denver Water's popular rebate program continues to help customers use less water. In 2010, outdoor commercial rebates were up 62 percent compared with 2009, and residential outdoor rebates were up 19 percent in that same time period. Also, residential indoor rebates were up about 45 percent from 2009. There are a number of other successful approaches that help customers conserve – from offering incentive contracts to high water users for reducing their water use to dispatching the award-winning *Use Only What You Need* advertising campaign throughout the city.

Every high-efficiency toilet installed or sprinkler turned off in the rain helps us all. Denver Water knows this, and will continue challenging customers to use only the water they need.

Customers are using  
20 percent less water  
than they were before  
the 2002 drought.

## Customers lead the way to smart water use

In the summer, Dagny Bruus' yard is an urban forest, lush with evergreens, maple and linden trees, and surrounded by a fence swallowed in wood ivy. She also enjoys bargain summer water bills. The highest, in fact, topped out at \$23.

"I water when it needs it," said the Denmark native, who now lives in central Denver. "Just think about how many people there are and how much water is wasted every day. We need to educate ourselves on using water."

Customers are reducing their water use, not because it's saving them money on their water bill (that helps, of course), but because they believe it's the right thing to do. Today, customers are using 20 percent less water than they did before the 2002 drought, even though there are 10 percent more of them.

"Our customers are leading us," said Greg Fisher, Denver Water's manager of demand planning. "We're just trying to help them."

The peak daily usage, which is the highest amount of water used in one day, also has decreased. In 1989, Denver Water customers used 553 million gallons of water in one day – the highest on record. In 2010, the most water used in one day was 365 million gallons, 34 percent less than in 1989.

Bruus, who has lived in her Denver house since the late 1980s, pays close attention to her outdoor water use. She waters her yard by hand in the evenings to avoid evaporation loss, washes her dishes in the sink and takes her laundry to a nearby laundry facility, which, she says, prevents her from washing partial loads.

"I don't want to die of thirst," she said with a laugh. "Respect nature. Be more in tune with nature."

Bruus isn't the only one with strong thoughts about the importance of conservation. Since 2006, Denver Water has

given customers more than 12,000 *Use Only What You Need* yard signs, one of the many advertising campaign elements that encourage customers to reduce their water use.

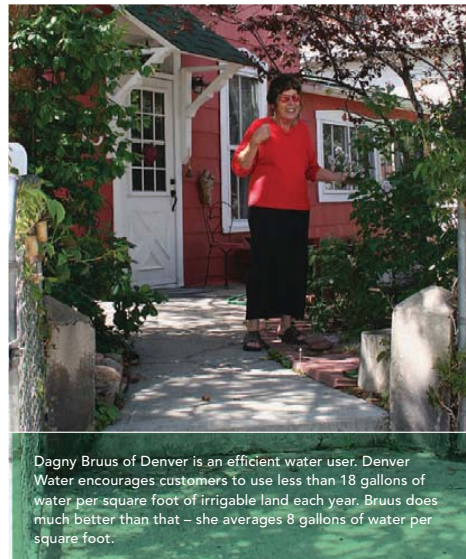
"People tell us they requested the sign to send a message to their neighbors," said Melissa Essex Elliott, Denver Water's conservation manager. "Our customers are incensed when they see water waste."

Denver Water's water waste hotline receives 2,500 calls a year from people reporting wasteful neighbors, businesses or parks. "We've even had people rat out their spouses," Elliott said.

Surveys have shown that people support water conservation. One recent study found that 80 percent of customers understand and comply with Denver Water's summer watering rules and 80 percent support Denver Water's *Use Only What You Need* message.

It's an important mission that's clearly resonating with customers.

"You can't take water for granted," Bruus said.



Dagny Bruus of Denver is an efficient water user. Denver Water encourages customers to use less than 18 gallons of water per square foot of irrigable land each year. Bruus does much better than that – she averages 8 gallons of water per square foot.

H

## Homeowners association reduces water use by 40 percent

When neighbors Mitch Albert and Ernie Joas first joined the board of their homeowners association, they inherited a \$500,000 problem: a 35-year-old irrigation system in rough shape. They knew there had to be a better way to fix the problem than to replace the entire irrigation system for such a large sum. If not, they faced having to raise dues for the 446 homes in Centennial's Heritage Place neighborhood just to keep 11 acres of greenbelts and common areas green and healthy.

They turned to Denver Water, which offers rebates and incentive contracts to large water users to help offset the cost of upgrading or installing new conservation equipment. Knowing that effective irrigation scheduling would be essential to saving water, they installed eight new weather-based smart controllers to regulate the irrigation system based on precipitation, soil makeup, wind and other factors. That project, along with rebates, earned the association roughly \$17,000 from Denver Water.

"The whole program makes good sense," Albert said.

But they didn't stop there. They overhauled the neighborhood's irrigation management, rebuilt the area's storm drainage to allow more water to soak into the plants rather than rushing to the streets, and pruned bushes to give sprinklers a clear, unimpeded spray to the grass.

They require the association's lawn care service to keep the grass height at 3.5 inches, which helps retain soil moisture better than short grass. They monitor the water meters every week to make sure the homeowners association is on track to meet its conservation goal. They also shortened the neighborhood's irrigation season. In the past, the sprinklers came on in April. Now, to take advantage of wet springs, the sprinklers don't go on until May.

And they were militant about finding and fixing leaks, often a major water-wasting culprit.

"We're obsessive about leak control," Joas said.

Their hard work has paid off, big time. Since their 2010 landscape overhaul and Denver Water incentive contract, Heritage Place has cut its water use by roughly 3 million gallons a year, which is about a 40 percent reduction, and is now saving about \$14,000 annually on the association's water bills.

That's a major improvement, and one Albert and Joas hope becomes permanent.



Mitch Albert, board treasurer, and Ernie Joas, board president, helped their homeowners association cut its water use by 40 percent by making major water-saving changes.



Invesco Field at Mile High has undergone a water-conservation overhaul, saving it millions of gallons of water each year.

Photo courtesy of Invesco Field at Mile High

## Mile-high water savings

Denver's famous football stadium has undergone a water-conservation overhaul, saving millions of gallons of water each year. "When you have a big complex like we do, small changes make a very, very big difference," said Andy Gorchov, general manager of Invesco Field at Mile High. "You can't be wasteful."

Invesco Field at Mile High has two Denver Water conservation projects in the works. One is a toilet retrofit project, in which Invesco replaced 142 toilets with high-efficiency models (1.28 gallons per flush), with help from more than \$17,000 worth of Denver Water toilet rebates. Swapping out those toilets is saving the stadium thousands of gallons of water each time it hosts an event.

The second project, which has cut the stadium's irrigation water use almost in half, is a Denver Water irrigation efficiency contract. Denver Water helps large-scale industrial and commercial customers tackle water-saving projects by providing them with incentive contracts to offset the cost of installing water-efficient irrigation equipment or low-water use landscape. In 2008, the stadium upgraded to a central control system that efficiently irrigates more than 230 zones surrounding the stadium.

The central control system allows the stadium's turf manager to adjust watering schedules on the stadium's 30 acres of land based on the plant's needs, Gorchov said. The new system cuts down on unnecessary watering by using

weather data from an on-site weather station, as well as information about precipitation rates, soil type, sun exposure and other factors, to adjust irrigation schedules accordingly.

Since installing the system in 2008, the stadium has saved an average of 6.8 million gallons a year in irrigation water use, and has received more than \$55,000 in Denver Water incentive payments. The stadium also has saved an average of \$25,000 a year on its water bills.

"These things make very good business sense," Gorchov said. "It's very expensive to waste."

## Water Savers hit the streets

Denver Water's crew of Water Savers has been patrolling the streets again this year, educating customers who are wasting water and rewarding those using water wisely.

A crew of summer employees, called the Water Savers, uses bright orange Use Only What You Need bicycles and fuel-efficient cars to comb neighborhoods in Denver Water's service area, looking for customers who aren't

following the summer watering rules. During the 2010 irrigation season, Water Savers made more than 5,000 stops to inform customers about watering rules and to educate them about the importance of conservation.

Often, the Water Savers notice people using water wisely – customers who used shut-off nozzles when washing their car, for example – and reward them with a Use Only What You Need freebie.

## Summary of Denver Water Conservation Goals

### (ACCELERATED CONSERVATION PLAN: 2007 - 2016)

Five years ago, Denver Water launched an aggressive 10-year plan to speed up the pace of conservation in its service area. The goal is to reduce overall water use 22 percent by 2016 in order to provide a secure water future for Denver Water customers. The following data provides a look at the different elements of the 10-year plan; however, this snapshot does not account for water savings achieved through customer behavior changes, which has been significant.

Accelerated Conservation Target (2007 – 2016) ..... 22% Reduction from Pre-Drought Use  
 Current Customer Demand ..... 20% Reduction from Pre-Drought Use  
 Remaining 2016 Conservation Target ..... Additional 2% Reduction from Pre-Drought Use

Program Activities, Incentives Paid and Estimated Savings: 2007-2010				
Program	Activity Level	Primary Customer Type	Incentives Paid	Estimated Savings
Conservation Outreach to City and County of Denver	66 contracts	Government	\$2.9 million	388 AF
Conservation Outreach to Suburban Government	16 contracts	Government	\$2.23 million	376 AF
Indoor Commercial/Industrial Incentive Contracts	37 contracts	Commercial/Industrial	\$991,382	385 AF
Commercial/Industrial Audits	214 audits	Commercial/Industrial	–	24 AF
Commercial/Industrial and New Construction Rebates	12,762 rebates	Commercial/Industrial	\$862,709	726 AF
Washing Machine Rebates	33,965 rebates	Residential	\$5.1 million	874 AF
Toilet Rebates	24,007 rebates	Residential	\$2.7 million	828 AF
Outdoor Residential Rebates	10,752 rebates	Residential	\$104,283	41 AF
Low Income Audits/Fixture Replacement	8,593 audits/8,210 toilet retrofits	Residential	–	535 AF
Irrigation Efficiency Incentive Contracts*	63 contracts	Commercial/Industrial	\$699,290	437 AF
High Bill Audits	1,300 audits	Residential	–	90 AF
Water Waste Rules Enforcement	11,305 stops	All	–	168 AF
Fixture Distributions	3,481	All	\$253,594	147 AF
Car Wash Recertifications	149	Commercial/Industrial	–	9 AF
Soil Amendments	2,026	–	–	131 AF
Outdoor Audits	214	All	–	27 AF
Multi-Family Audits/Units Audited	49 audits/6,120 units audited	Residential	–	189 AF
Total acre-feet savings from programs: 5,374 acre-feet				

\* Irrigation efficiency incentive contracts are paid over five years. The incentives paid (\$) amount reflects incremental annual payments made for contracts in progress, not full payment in one year.

## Master plan sets the path for recycled water's future

The last time Denver Water updated its master plan for its recycled water system was in 2004 – the same year the recycled water treatment plant opened. “We’ve gathered a lot of information since then,” said Abigail Holmquist, Denver Water’s recycled water program manager.

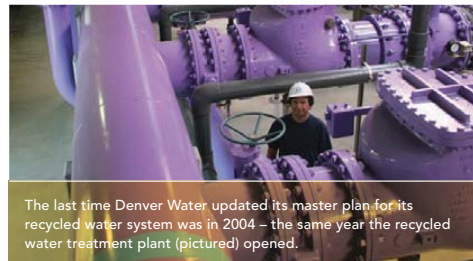
Denver Water recently revised its Recycled Water Master Plan, a document that helps plan for future growth. It outlines potential customers, details what infrastructure should be installed and analyzes the expense of adding different customers to the system.

The master plan identifies almost 300 potential customers – up from 100 in the 2004 update – which will help Denver Water reach its goal of delivering 17,500 acre-feet of recycled water each year. Recycled water is treated wastewater used for irrigation, commercial and industrial use, freeing up drinking water for other purposes.

Once build-out is complete, expected in the next decade, Denver Water’s recycled water system will free up enough drinking water to serve almost 43,000 homes. So far, Denver Water is about one-third of the way toward its goal.

In 2010, Denver Water expanded the recycled water system to serve irrigation customers, including:

- East High School grounds
- Sixth Avenue median, between Uinta Parkway and Roslyn Street in Lowry
- Ulaanbaatar Park in Lowry
- Fifth Avenue median, from Roslyn Street to Quebec Street in Lowry
- Stanley British Primary Soccer Field in Lowry
- Montclair Recreation Center Playing Fields in Lowry
- Westerly Creek School grounds in Stapleton
- Stapleton Central Park Recreation Center



In addition to adding recycled water service at the Rocky Mountain Arsenal and expanding its use at the Denver Zoo, Denver Water plans to add parks and schools in the Montbello neighborhood and irrigation customers near Peña Boulevard and Interstate 70, eventually supplying recycled water to Denver International Airport. In the next decade, Denver Water plans to extend service to areas that include the University of Denver and Observatory Park.

## Golf course receives recycled water award

CommonGround Golf Course, which irrigates its course with Denver Water’s recycled water, was one of eight winners of the 2010 WateReuse Award of Merit.

The award, presented by the WateReuse Association, recognizes projects for their significant contributions to the water reuse and desalination industry.

CommonGround Golf Course, a public course that opened in 2009 on the site of the former Mira Vista Golf Course southeast of Lowry, hooked onto Denver Water’s recycled water system to help make the course as water-efficient and environmentally friendly as possible.



the Mountain Arsenal was producing instead, Denver Water will start delivering recycled water to the area. The Army is also expanding by late 2011 there will be dedicated lines to the lake. The Littleton, Littleton City and the City of Aurora will have wetlands. The large area plant to see recycled water through 30 miles of cast-iron pipes, which the Army installed in the 1950s, to irrigate freshly planted short-grass prairie, helping the native grassland establish and fend off noxious weeds.

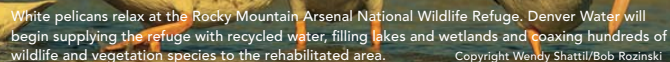
wildlife refuges in the country. The site no longer receives raw water from the High Line Canal, mainly because the canal lost water to seepage and often washed sediment, pesky weed seeds and nonnative fish larvae into the lakes.

Instead, Denver Water will start delivering recycled water to the area expanded by late 2011. Here will be dedicated lines to the lake. Littleton, Littleton, Littleton and Littleton will be well to wetlands. The huge application to see recycled water through 30 miles of cast-iron pipes, which the Army installed in the 1950s, to irrigate freshly planted short-grass prairie, helping the native grassland establish and fend off noxious weeds.

"We're essentially bringing this area back to the way it was in the 1850s," Jackson said.

The refuge plans to supplement recycled water with well water, but recycled water is crucial to re-creating that stable ecosystem.

"Absent the recycled water," Jackson said, "we'd be in a world of hurt."



## Denver Zoo's new exhibit uses recycled water

Elephants, rhinoceroses and tapirs in one of North America's largest elephant habitats will swim and kneel in recycled water from Denver Water.

Denver Zoo's Asian Tropics, the largest exhibit in the zoo's history, is under construction and planned to open in 2014. Once finished, the 10-acre Asian Tropics site will utilize more than 2 million gallons of water – more than the rest of the zoo combined – but its impact on drinking water supplies will be minimal. All of the water used for exhibits and irrigation will come from Denver Water's recycled water system, freeing up drinking water for other purposes, and 900,000 gallons of it will be recirculated through the site's filtration building.

If all goes as planned, Asian Tropics will achieve the highest standard in Leadership in Energy Efficiency Design (LEED) from the U.S. Green Building Council. Doing so will acknowledge the site's environmentally sustainable practices. And one of the components of LEED certification is using recycled water, something the zoo has done since 2004.

"The ability to reuse our natural resources fits perfectly with Denver Zoo's core values of conservation," said Steve Salg, Denver Zoo project manager.

Denver Zoo's Front Entry/Predator Ridge exhibit, built in 2004, was the first area of the zoo to use recycled water. Now, the zoo uses about 2 million gallons of recycled water each year for irrigation, enclosure washdown and animal swimming pools. Because Denver Water's recycled water rates are roughly 70 percent less than potable water rates, the Denver Zoo saves more than \$100,000 each year in water costs.

"The zoo has been extremely progressive with their use of reclaimed water," said Abigail Holmquist, Denver Water's recycled water program manager.

Though recycled water is not meant for human consumption, the zoo's veterinarians have found it perfectly suitable for Asian elephants, clouded leopards, Asian small-clawed otters,

Malayan tapirs and other animals that will soon call Asian Tropics their home. The animals will roam 10 acres of mud wallows, scratching trees and pools in a \$50-million facility with state-of-the-art efficient features.

The site's biomass gasification system, for example, will allow the zoo to use 90 percent of its animal waste and human trash to generate clean energy for Asian Tropics, reducing the zoo's landfill trash by 1.5 million pounds per year.



Mimi, an Asian elephant at the Denver Zoo, plays with a fallen tree. The zoo's elephants, rhinoceroses, tapirs and other Asian animals will soon swim and bathe in recycled water from Denver Water. Photo courtesy of Dave Parsons, Denver Zoo

And expanding the zoo's recycled water service to include Asian Tropics will help the zoo achieve its goal of using more recycled water. In fact, once the zoo's master plan buildout is complete, recycled water will account for 90 percent of the zoo's total water consumption, freeing up enough drinking water to serve roughly 1,250 houses.

### Recycled Water 101

Several schools in Denver Water's service area receive recycled water to irrigate their fields and landscaping. Why not teach students at those schools – and others – about the benefits of using recycled water?

Denver Water's Youth Education Program focuses on outreach and educational support to kindergarten through 12th grade students, their teachers and school district.

Every sixth-grade Earth science classroom in Denver Public Schools receives a copy of Denver Water's *Teacher Resource Packet*, full of water curriculum-supporting materials. For schools that receive recycled water for irrigation, Denver Water supplements the resource packet with literature about recycled water. Denver Water also offers tours of the recycled water plant, and staff members have visited several schools to talk to students about recycled water.

## Proposed agreement sets the stage for regional cooperation

The way water is managed in Colorado is about to change, thanks to the recent announcement of the proposed Colorado River Cooperative Agreement. With 35 partners, stretching from Grand Junction to the Denver-metro area, the proposed agreement is the largest of its kind in state history. This agreement demonstrates that “collaboration works, and collaboration can move mountains,” said Gov. John Hickenlooper at the announcement, before joking, “Collaboration can move water lawyers.”

Focused on cooperation, the proposed agreement brings parties who traditionally have been at odds together as partners on a path to responsible water development benefitting both the East and West Slopes. It achieves better environmental health for the Colorado River Basin, maintains high-quality recreational use and improves economics for many cities, counties and businesses impacted by the river. The proposed agreement, which was five years in the making, will now be considered by towns, counties, and water entities from the headwaters to the Utah state line.

“We negotiated hard,” Denver Water’s CEO/Manager Jim Lochhead said. “We had a number of

objectives, and I believe we’ve achieved them with this agreement.”

In addition to its benefits for Denver Water and the West Slope, the proposed agreement will trigger a major water-sharing and conservation arrangement between Denver Water, Aurora Water and water providers in the South Denver-metro area. Taken as a whole, these landmark agreements mark the most significant change Colorado has seen in how the state’s water resources are managed.

The comprehensive proposed agreement focuses on significantly enhancing the environmental health of much of the Colorado River Basin and its tributaries, as well as supporting many West Slope cities, towns, counties and water providers as they work to improve the quality and quantity of water through new municipal water projects and river management initiatives.

In exchange for environmental enhancements, including financial

support for municipal water projects, additional water supply and service area restrictions, the agreement will remove opposition to Denver Water’s Moffat Collection System Project.

The Colorado River Cooperative Agreement also establishes a process, dubbed Learning by Doing, by which Denver Water, Grand County, the Colorado River District, the Middle Park Water Conservancy District and others will use the flexibility in Denver Water’s water system to manage river flows for the benefit of the environment in Grand County.

There is still plenty of work to do. Eighteen parties must sign the agreement, without making changes, before it becomes official. Lochhead said the group’s goal is to have the agreement fully executed by the end of 2011.

“It positions Denver Water and our system to develop additional supplies,” Lochhead said. “It positions Colorado to use water efficiently and use the water supplies we have in the best way.”



Fall colors surround the Eagle River, a tributary of the Colorado River. The proposed Colorado River Cooperative Agreement brings parties who traditionally have been at odds together as partners on a path to responsible water development, benefitting both the East and West Slopes. Photo ©iStockphoto.com/Scott Cramer

# WATER INFRASTRUCTURE

## Regional partnership in work to meet future water needs

Seventeen entities, including Denver Water, are joining forces on a project that may supply customers with more water while minimizing the need to buy new water rights.

Denver Water is moving forward with the partnership called WISE, which stands for Water, Infrastructure and Supply Efficiency. If implemented, the partnership will provide new supply by combining unused capacities in Aurora Water's Prairie Waters Project with unused water supplies from Denver and Aurora. Then, during years Denver and Aurora don't need all of that water, the 15 Douglas County entities that constitute the South Metro Water Supply Authority can buy the unused water to help reduce their reliance on nonrenewable groundwater.

"It's a great example of a cooperative regional effort that benefits everybody," said Dave Bennett, project manager for WISE. "It's also the most complex project we've ever worked on."

The partnership has not been finalized and much work remains. But if all goes as planned, Denver Water will start capturing its unused water and selling it to South Metro in the next few years. Initially, that will provide Denver Water with up to \$2.25 million per year in revenue.

This cooperative effort is rare in Colorado, which divvies water based on a first-in-time, first-in-line style of water rights called prior appropriation.

"The way Colorado water has historically been developed has been every man for himself," Bennett said.

"That has produced a lot of haves and have-nots. Whoever got there first, like Denver Water, got senior rights. Water providers that came later, like South Metro, didn't get those rights."

Those kinds of rules brought about years of legal wrangling over every drop of water.

But WISE is different.

After the 2002 drought, Aurora Water knew it needed to find more water

*continued>*



R

supplies and fast. If the city had another horribly dry year after 2002, “they would’ve been in trouble,” Bennett said.

So Aurora, which is one of the largest water providers in the state, built the Prairie Waters Project. The \$653 million operation began in fall 2010, increasing Aurora’s water supply by 20 percent. The project allows Aurora Water to collect South Platte River water it owns from wells just north of Brighton. The water is then piped 34 miles south to a new purification facility near Aurora Reservoir, where it is treated and delivered to Aurora customers.

Such a massive project required a lot of infrastructure. And during the winter, when people aren’t watering their lawns and putting such a demand on the system, Aurora has extra capacity in its infrastructure.

Denver Water saw that underused infrastructure as an opportunity to capture reusable water in the South Platte River for a new emergency supply. At the project’s completion, Denver Water expects to capture about 15,000 acre-feet of unused supply – enough to serve almost 38,000 homes. When Denver Water doesn’t need that emergency supply, it plans to sell the excess to South Metro, which relies heavily on nonrenewable aquifers and wells.

The water that Denver will put into WISE is primarily reusable return flows from its Blue River supplies. No new diversions will be needed in Denver’s mountain system to provide WISE water.

## Front Range Water Council unites water suppliers

Front Range water suppliers face very similar challenges and issues. In an effort to work cooperatively on a variety of issues of mutual interest, the Front Range Water Council was created in 2008. Its members include:

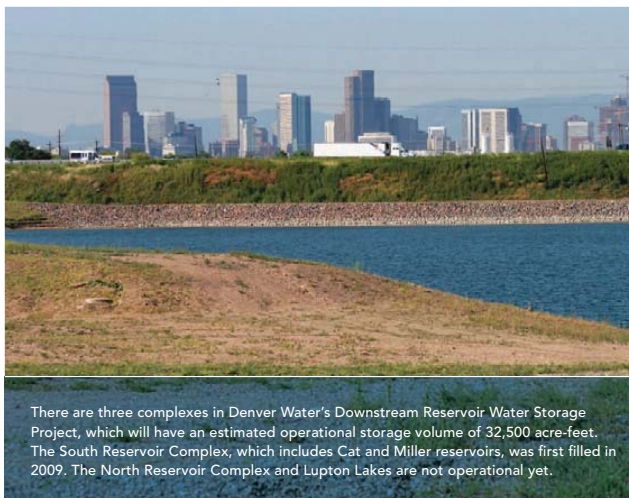
- Denver WaterN
- Aurora WaterN
- Colorado Springs UtilitiesN
- Northern WaterN
- Pueblo Board of Water WorksN
- Southeastern Colorado Water Conservancy DistrictN
- Twin Lakes Reservoir and Canal CompanyN

These utilities and districts meet the water demands of 4 million people – 82 percent of Colorado’s population – with just 20 percent of the state’s total water supply. Most of this water supports agriculture; just 6.5 percent serves municipal and industrial purposes. And more than 80 percent of Colorado’s economy and tax revenue comes from the areas served by the Front Range Water Council.

In addition to investing in water conservation, efficiency and recycled water, Front Range Water Council members are meeting future water demands through innovative water supply projects. Council members have invested more than \$1.4 billion in recent capital projects, and have budgeted another \$4.6 billion for such projects in the next decade. This will ensure that future water needs are met while creating jobs and growing the state’s economy.

The Front Range Water Council works closely with the Colorado Water Conservation Board and the environmental community to develop credible future project planning scenarios and measurement metrics to close Colorado’s water supply gap. In order to successfully meet Colorado’s water needs, the Front Range Water Council supports the position that identified projects and processes, new supply development, agriculture-to-urban water partnerships and conservation must be simultaneously pursued.

## Gravel pits find new life



One of the best things about using old gravel pits for water storage is that usually, someone else does much of the work to build them. "Mining companies have to reclaim the land they mine," said Greg Gulley, project engineer for Denver Water's Downstream Reservoir Water Storage Project. "Turning them into reservoirs is a way to reclaim a gravel pit after it's mined."

In 2009, Denver Water filled its first two gravel pits with water. That was the first time Denver Water has converted gravel pits into reservoirs, and it won't be the last.

The Downstream Reservoir Water Storage Project, which has been in the works for more than a decade, allows Denver Water to store and release reusable water in its system through the

use of old gravel pits that have been improved to store water.

With this project, Denver Water can keep upstream water while releasing water from gravel pits north of the city to meet water requirements of downstream users.

There are three complexes in the project, which will have an estimated operational storage volume of 32,500 acre-feet. The South Reservoir Complex, which includes Cat and Miller reservoirs, was first filled in 2009.

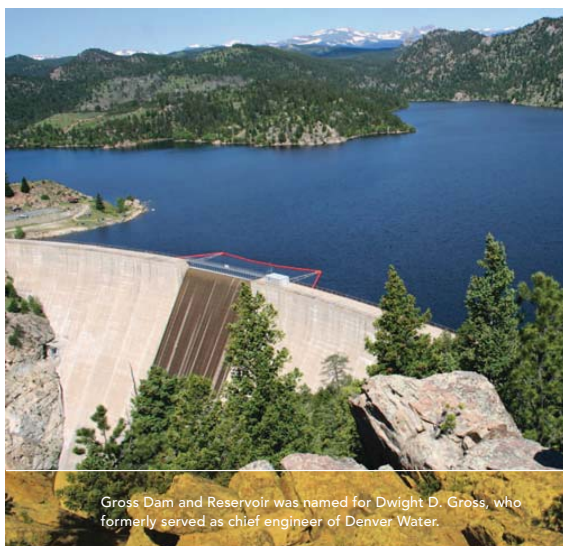
Now, Denver Water is moving forward with its North Reservoir Complex, south of 120th Avenue and east of the South Platte River. There are five gravel pits in the complex, including Howe-Haller A, Howe-Haller B, Hazeltine, Dunes and Tanabe reservoirs.

To prepare those gravel pits for their water-storing future, Denver Water needs to construct infrastructure at the site. In 2010, Denver Water built the Fulton Inlet Pipeline to deliver water from the Fulton Ditch to reservoirs in the North Complex. Crews also continue to mine the Hazeltine Reservoir site and remove excess material to increase the reservoir's storage capacity.

In 2011, Denver Water plans to build an outlet structure for Dunes Reservoir and a connection to the Fulton Inlet Pipeline so water can be moved in and out of Dunes. If all goes as planned, the North Complex reservoirs will be fully operational in 2016.

There's still plenty to do to prepare now and then, though. Denver Water needs to line Hazeltine Reservoir to stabilize the slopes. Denver Water also must build a pump station at Hazeltine to release water from the North Complex into the South Platte River and to pump water into Tanabe and Dunes reservoirs. That station, which is partially designed, will be the most expensive portion of the North Complex aside from land acquisition, Gulley said.

At the same time, Denver Water continues to move forward on its third complex. The Lupton Lakes complex, near Fort Lupton, is still being mined and is expected to begin operating sometime after 2020.



Gross Dam and Reservoir was named for Dwight D. Gross, who formerly served as chief engineer of Denver Water.

## Moffat project looks to minimize impact

Several projects that will benefit the environment in Grand County, Summit County and the Colorado and Fraser rivers, among other areas, hinge on the approval of the Moffat Collection System Project.

"We're not looking at enhancing just one thing," said Travis Bray, project manager for the Moffat project. "We're doing several. We're improving fisheries. We're helping stream habitat. We're improving water quality. What can we do to meet everybody's requests?"

The Moffat Collection System Project will more than double the capacity of Gross Reservoir, located west of Boulder, providing Denver Water with 18,000 acre-feet of additional supply – enough water to serve about 45,000 households annually.

But the project will do much more than provide Denver with more water. About 80 percent of Denver Water's raw water comes from the south end of its system. The Moffat project, located on the north end of the system, will ease some of the pressure on the south side and improve Denver Water's operational flexibility, ensuring Denver

Water will continue to supply customers with a reliable water supply, especially during droughts and emergencies.

The U.S. Army Corps of Engineers continues to study the project and respond to public comments. The Corps plans to release a Final Environmental Impact Statement by the end of 2011, and if all goes as planned, the project will be operational in next decade.

Once that happens, the flexibility gleaned from such an important project will allow Denver Water to provide environmental enhancements, while ensuring an adequate water supply for customers.

Denver Water is proposing several mitigation and enhancements projects if the Moffat project is built. Among those include:

- 1,000 acre-feet of additional flows each year for the Fraser River. That extra water will help improve fisheries and stream habitat.
- More water in the Fraser River for Grand County to use as its population grows.
- Money to improve aquatic habitat and water quality in Grand County.
- Money for Summit County projects to enhance the environment, such as making improvements to a wastewater treatment plant that will improve effluent water quality.
- 1,000 acre-feet of water in Williams Fork Reservoir.
- Stream restoration work below Windy Gap Reservoir to improve the Gold Medal fishery.
- 5,000 acre-feet of water in Gross Reservoir to improve aquatic habitat in South Boulder Creek.

The Colorado Wildlife Commission and the Colorado Water Conservation Board recently approved Denver Water's plan to alleviate impacts to fish and wildlife caused by the proposed Moffat project. For more information, visit [www.denverwater.org/moffat](http://www.denverwater.org/moffat).



**WANT**



**NEED**

**USE ONLY  
WHAT YOU  
NEED.**

 **DENVER WATER**

## **Appendix A-4**

**Summary of 2002 Demand Model Update, Technical Memorandum,  
prepared by Mary Price, Demand Planning, Denver Water, April 2, 2012**



#### **APPENDIX A-4**

DATE: April 2, 2012

TO: Ed Harvey, Principal, Harvey Economics  
Greg Fisher, Manager of Demand Planning, Denver Water

FROM: Mary Price, Demand Planning, Denver Water

RE: Summary of 2002 Demand Model Update

Denver Water's 2002 demand model breaks demand into three sectors: single family residential; commercial / industrial / multifamily; and institutional (governmental). Each of these demand sectors is a separate model with a distinct regression equation consisting of different variables. Some variables appear in more than one equation, some are unique to only one. The variables include Population, Employment, Number of Single Family Households, Number of Multifamily Households, Household Income, People per Household, Irrigation Season Precipitation, Marginal Price, Average Conservation Spending, and Percent of Accounts Metered.

Denver Water Demand Planning staff has updated Denver Water's 2002 Demand Model with 2010 data. Updated numbers for each variable in the model (with two exceptions) were obtained and utilized in the original regression model. The exceptions were Irrigation Season Precipitation and Percent of Metered Accounts, neither of which had changed since 2002 and so were held at the original 2002 Model values (9.4 inches and 100% respectively).

#### Sources for 2010 Data

The demographic information (Household Density, Number of Persons per Household, Employment, Population and Number of Households) was updated based on the 2010 regional forecast from Denver Regional Council of Governments (DRCOG). Denver Water relies on DRCOG's geographic distribution of its demographic forecast because Denver Water's Combined Service Area comprises only a portion of six counties of DRCOG's planning area. DRCOG performs this distribution of the future growth in the metro area for its own planning purposes. The forecast is prepared under the direction of DRCOG's Economic Task Force, a group of economic and demographic experts within the region. This 2010 forecast extends to the year 2035. Denver Water used the growth rates from the original 2002 demand model data to extend DRCOG's forecast to 2050.

The number of Single Family (SF) Households and Multifamily (MF) Households are based on DRCOG's total Number of Households, but are split on a 60/40 basis (SF versus MF), rather than the 50/50 basis assumed in the original 2002 model data. The 60/40 ratio was adopted as part of the 2010 data update because it reflects the current ratio of SF to MF units across the Metro area counties (Adams, Arapahoe, Denver and Jefferson).

Household Income was updated using Median Household Income from the American Community Survey provided by the US Census Bureau, and the Denver-Boulder Metro area CPI. The rate of growth used for projecting future income was obtained from long-term estimates of US Income growth from the Social Security Administration 2009 Annual Report.

The Single Family and Institutional Marginal Price variables were updated using the Denver Water Annual Report and the Denver-Boulder Metro area CPI and projected using the same growth rate as the 2002 model.

Finally, the three year average conservation spending variable was updated using Denver Water's 2010 value, adjusted to a 1983 basis to match the specifications of the model.

The updated variable values are listed in Attachment 1. The growth rates for each variable are detailed in Attachment 2.

#### Updated Model Results

There are significant differences between the 2050 values of some of the variables in the original and in the updated model (see Attachment 2). However, the difference between 2050 demand in the original model and in the updated model is less than 5% (see Attachment 3). As shown below, the total unconstrained demand for 2050 increases by 3% (see Table1b).

<b>2002 Demand Model - 2050 Demand in Acre-Feet</b>		
	<b><u>2002 Data</u></b>	<b><u>2010 Data</u></b>
<b>2050 Demand (Model Only):</b>	391,675	404,100
<b>Plus Fixed Contracts</b>	66,600	66,600
<b>Plus Historic Conservation</b>	29,000	29,000
<b>2002 Model - Unconstrained 2050 Demand</b>	487,275	499,700

The primary driver of this demand change is the 11% increase in the updated 2050 employment projections for the Denver Water service area. Employment is the most significant factor in the models for both the Commercial/Industrial/Multifamily and the Institutional sectors. Both sectors are projected to increase their 2050 demand by close to 10% in the updated 2002 model estimates.

The 3% overall increase in modeled demand happens despite a 3% decrease in the projected 2050 modeled demand for the single family residential customers, brought on primarily by the 32% decrease in projected 2050 household income. However, the effect of this decrease in household income is counter-balanced by the projected increase in the number of single family households by 2050. While the overall increase in DRCOG's 2050 projection of the number of households is modest, the updated 60/40 SF to MF ratio amplifies that impact.

**Attachment 1**  
**Projected Economic and Demographic Data – 2010 Update**

	Household	Household	Irr. Season	# Persons	Percent	Single Family	Institutional	3-Yr Average	Single	Multifamily			
	Income	Density	Precipitation	per	Metered	Marginal	Marginal	Conservation \$	Family	Number of	Employment	Population	Households
				Household		Price	Price		Households	Households			
2000	\$ 35,000	2.84	9.4	2.35	100%	\$ 0.99	\$ 0.72	\$ 1,149,949	244,199	199,793	802,019	1,043,652	443,992
2005	\$ 30,300	4.17	9.4	2.29	100%	\$ 1.23	\$ 0.89	\$ 1,149,949	271,800	199,697	823,510	1,108,826	471,496
2010	\$ 28,317	5.50	9.4	2.22	100%	\$ 1.46	\$ 1.06	\$ 1,149,949	299,400	199,600	845,000	1,174,000	499,000
2015	\$ 28,430	4.50	9.4	2.22	100%	\$ 1.54	\$ 1.12	\$ 1,149,949	315,000	210,000	923,000	1,231,000	525,000
2020	\$ 28,544	4.00	9.4	2.22	100%	\$ 1.61	\$ 1.17	\$ 1,149,949	333,000	222,000	985,000	1,297,000	555,000
2025	\$ 28,659	3.70	9.4	2.21	100%	\$ 1.70	\$ 1.23	\$ 1,149,949	352,200	234,800	1,067,000	1,363,000	587,000
2030	\$ 28,773	3.45	9.4	2.19	100%	\$ 1.78	\$ 1.30	\$ 1,149,949	376,200	250,800	1,157,000	1,431,000	627,000
2035	\$ 28,889	3.20	9.4	2.16	100%	\$ 1.87	\$ 1.36	\$ 1,149,949	400,200	266,800	1,247,000	1,499,000	667,000
2040	\$ 29,004	3.20	9.4	2.16	100%	\$ 1.97	\$ 1.43	\$ 1,149,949	418,951	279,301	1,293,827	1,569,234	698,252
2045	\$ 29,121	3.20	9.4	2.16	100%	\$ 2.07	\$ 1.51	\$ 1,149,949	438,581	292,387	1,342,412	1,642,760	730,968
2050	\$ 29,237	3.20	9.4	2.15	100%	\$ 2.18	\$ 1.58	\$ 1,149,949	459,130	306,087	1,392,822	1,719,730	765,217

## Attachment 2

### Comparison of 2050 Variable Values; Projected Growth Rates

2050 Values	Household <u>Income</u>	Household <u>Density</u>	Irr. Season <u>Precipitation</u>	# Persons <u>per Household</u>	Percent <u>Metered</u>	SF Marginal <u>Price</u>	Inst. Marginal <u>Price</u>	3-Yr Average <u>Conservation \$</u>	SF # of <u>Households</u>	MF # of <u>Households</u>	<u>Employment</u>	<u>Population</u>	<u>Households</u>
2002 Model @ 2002	\$42,732	3.55	9.4	2.30	100%	1.66	1.36	1,116,000	378,990	378,990	1,250,666	1,743,353	757,980
2002 Model @ 2010	\$29,237	3.20	9.4	2.15	100%	2.18	1.58	1,149,949	459,130	306,087	1,392,822	1,719,730	765,217
% Change from 2002	-32%	-10%	0%	-6%	0%	31%	16%	3%	21%	-19%	11%	-1%	1%
Growth Rate	Avg Annl Growth Rate of 0.08%	0%	NA	Avg Annl Growth Rate of -0.02% from 2040 to 2050	NA	Average Annual Growth Rate of 1%	Average Annual Growth Rate of 1%	NA	NA	NA	Avg Annl Growth Rate of 0.74% from 2040 to 2050	Avg Annl Growth Rate of 0.92% from 2040 to 2050	Avg Annl Growth Rate of 0.92% from 2040 to 2050
Source	Long-term growth rate from 2009 Social Security Administration Annual Report	Held steady at 2035 number no better data	Assumed Constant Value	Assumed Growth Rate from 2002 Model	Assumed Constant Value	Assumed Growth Rate from 2002 Model	Assumed Growth Rate from 2002 Model	Assumed Constant Value	Uses total hh # - 60/40 split between SF and MF based on 2009 Metro Area Counties ratio	Uses total hh # - 60/40 split between SF and MF based on 2009 Metro Area Counties ratio	2002 Demand Model Rate of Change	2002 Demand Model Rate of Change	2002 Demand Model Rate of Change

**Attachment 3**  
**Projected Demand Model Summary**  
**2002 Model w/2010 Demographic Data**

Year	Single Family	Commercial/ Industrial/ Government		Total	Thousands of Gallons		
		Multifamily			5% Calibration Adjustment	6% System Loss Adjustment	AF Total
2000	37,097,590	28,591,779	7,493,460	73,182,830	76,841,972	81,452,490	249,969
2005	35,829,793	29,311,007	7,567,933	72,708,733	76,344,170	80,924,820	248,350
2010	34,900,842	30,030,234	7,642,406	72,573,482	76,202,156	80,774,285	247,888
2015	38,470,577	32,719,154	8,311,792	79,501,523	83,476,599	88,485,195	271,552
2020	41,499,571	34,883,754	8,834,116	85,217,440	89,478,313	94,847,011	291,076
2025	44,253,229	37,724,194	9,535,798	91,513,221	96,088,882	101,854,215	312,580
2030	47,400,982	40,855,994	10,307,896	98,564,872	103,493,115	109,702,702	336,666
2035	50,549,284	43,987,794	11,077,738	105,614,816	110,895,556	117,549,290	360,747
2040	52,606,668	45,647,751	11,453,631	109,708,050	115,193,453	122,105,060	374,728
2045	54,726,106	47,370,892	11,842,982	113,939,980	119,636,979	126,815,197	389,183
2050	56,906,895	49,159,627	12,246,263	118,312,785	124,228,424	131,682,130	404,119
2002 Model w/2010 Demo (AF)	174,641	150,866	37,583	363,090	381,244	404,119	
2002 Model w/2002 Demo (AF)	179,920	137,884	34,106	351,910	369,506	391,676	
2010 Demo from 2002 Demo	-3%	9%	10%	3%	3%	3.2%	



**Table 1b.**  
**2002 Demand Model – 2050 Demand in Acre-Feet**

	<u><b>2002 Data</b></u>	<u><b>2010 Data</b></u>
<b>2050 Demand (Model Only):</b>	391,675	404,100
<b>Plus Fixed Contracts</b>	66,600	66,600
<b>Plus Historic Conservation</b>	29,000	29,000
<b>2002 Model - Unconstrained 2050 Demand</b>	487,275	499,700



**Appendix A-5**  
**Update of Denver Water Demand Projections, Technical Memorandum,**  
**prepared by Harvey Economics, April 2, 2012**





Harvey Economics ♦ 600 South Cherry Street, Suite 220 ♦ Denver, Colorado 80246  
tel. 720.889.2755 ♦ fax 720.889.2752 ♦ [www.harveyeconomics.com](http://www.harveyeconomics.com) ♦ [he@harveyeconomics.com](mailto:he@harveyeconomics.com)

**APPENDIX A-5**  
**MOFFAT COLLECTION SYSTEM PROJECT EIS TECHNICAL MEMORANDUM**

**SUBJECT:** UPDATE OF DENVER WATER DEMAND PROJECTIONS

**DATE:** APRIL 2, 2012

**PREPARED BY:** HARVEY ECONOMICS

---

**Introduction**

The U.S. Army Corps of Engineers (CORPS) received a number of comments on the draft Moffat Collection System Project EIS (EIS) related to the need for updated water demand projections. The commentators pointed out that the water demand projections were published in 2002 and based upon projections developed prior to that date. With the fluctuating levels of economic activity which have taken place at the national, state of Colorado, and Denver metropolitan area levels since 2002, the CORPS and its third party contractors agreed with these comments and took actions pursuant to updated water demand projections which led to an update of the Purpose and Need component of Chapter 1 of the EIS.

Under the direction of Harvey Economics (HE), one of the third party contractors, the following steps were completed:

- 1) Review of the Purpose and Need section of Chapter 1 to determine what information required updating;
- 2) Request to Denver Water to update the water demand projections;
- 3) Review and validation of the Denver Water demand projection update; and
- 4) Incorporate updated water demand information into the final EIS.

Each of these steps is described in detail below.

## **Determination of Update Requirements**

The Moffat DEIS, and Appendix A to the DEIS defines and describes the water demand projection techniques utilized for the Moffat EIS. As described in those previous documents, Denver Water uses an econometric model to project future water demands. The econometric model is actually a composite of three sub-models: One, estimating future single-family water demand; two, estimating commercial, industrial and multi-family water demand; and three, estimating government and institutional water demand. The results of these three models are then adjusted for calibration, system losses, natural replacement, conservation and fixed contracts to determine total system-wide water demand. The methodology and data sources employed in these projections were fully evaluated and deemed appropriate for the EIS, as set forth in Appendices A-1 and A-2 of the DEIS.

Upon review of these 2002 water demand projection, HE determined that the primary need was an update of the economic and demographic information, both historical and projected, that represented input variables to the three water demand forecasting sub-models. HE also sought updated information concerning conservation, natural replacement, and system supply adjustments.

HE determined that a re-estimation or new configuration of the water demand models was not needed. The water demand models were originally estimated using 27 years of economic demographic, data which is believed to be the sufficient historical period for estimating regression coefficients. HE concluded that the structure of the 2002 water demand forecasting models remained sound and appropriate for projecting water demands in 2011.<sup>1</sup>

## **Update of Economic Demographic Projections**

On September 14, 2010, HE met with Denver Water and requested an update of the economic and demographic information which were inputs to the water demand forecasting model. These inputs are identified in Exhibit 1.

---

<sup>1</sup> Denver Water is in the process of completing a new version of its integrated resource plan. Other forecasting techniques might be employed in that IRP, but those forecasting approaches were not available for review at the time of this update.

**Exhibit 1.**  
**Independent Variables in the Denver Water Demand Model.**

Variable Name	Description
HHINC	Income per household
DISTDENS	Number of housing units per acre
IRRPC	Inches of precipitation during the growing season (May to October)
POPPERHH	Population per household
PCTMETER	Percent of customers metered
MGRPR (SF)	Marginal price of water for single family households
MRGPR (Instit)	Marginal price of water for institutional users
3YRAVG DOL	Three year average of annual conservation expenditures
MFHH	Number of multi-family households
EMPLMENT	Number of persons employed in the service area by place of work

Source: U.S. Army Corps of Engineers Omaha District, Moffat Collection System Project Preliminary Draft Environmental Impact Statement Appendix A. November, 2008.

HE requested that Denver Water provide an update of this information based upon historical data through the year 2010, and then the most recent and reliable projections of these data for 2032, the forecasting horizon of the Moffat EIS and through 2050. The information provided by Denver Water is included as a Memorandum in Appendix A-4.

**Review and Validation of Denver Water's Updated Projections**

HE reviewed each of the economic and demographic projections provided by Denver Water. The data sources and projections were found to be the most recent and supportable projections available for this purpose. Individual projections and data sources are discussed below.

**HHINC.** Household incomes over the past decade fell by an annual average of 0.3 percent on a constant dollar basis, reversing a long term trend of increases. As a result, projected 2032 household incomes in the model have been reduced from \$39,500 in the 2002 version to \$28,800 in the updated model. The household income projections are based upon the Census and the American Community Survey, both by the U.S. Census Bureau. These data were projected forward using the average annual growth rate from 1969 to 2009 for the Denver Metro area of 0.11 percent.

**DISTDENS.** Household density has increased over the last decade with new urban centers and the housing downturn during the 2000 to 2010 decade. The Denver Regional Council of

Governments (DRCOG) provided a projection of household density to 2035, suggesting that housing units per acre will return to more normal patterns over the long term.

**IRRPC.** The inches of precipitation during the growing season (May to October) were obtained from the National Oceanic and Atmospheric Administration's (NOAA) *Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1971 – 2000* publication. The number used in the model is the 30 year average precipitation (May to October) in the Denver area. NOAA is the authoritative source for precipitation information and this is the most recent publication containing historical data on the Denver area. This variable did not require updating.

**POPPERHH.** The average population per household is also estimated by DRCOG. Again, the DRCOG projections are the latest estimates for the Denver Metro area. This estimate is for all homes; DRCOG does not distinguish between single family and multifamily homes for this statistic.

**PCTMETER.** Denver Water provided the percentage of metered customers. All accounts are metered, since the early 1990's. All new accounts in the future will also be metered.

**MGRPR (Single Family and Institutional).** The marginal price of water (the price of the last gallon purchased) also was provided by Denver Water based on billing records. Denver Water's own projections of water price based upon data through 2010 are considered the best source for this information.

**3YRAVG DOL.** The three year average amount spent on conservation is also forthcoming from Denver Water and has been updated through 2010. However, this variable is only in the model to account for the historical amount of water conserved. It is based on historical conservation spending and does not change into the future.

**MFHH.** The number of multifamily homes is estimated by taking the total number of households and multiplying it by the ratio of single and multifamily households. The split of 60 percent single family and 40 percent multifamily has been fairly constant for the last decade.

The total number of households was projected by DRCOG and is the latest projection for the Denver Metro area.

**EMPLMENT.** Employment by place of work is projected by DRCOG; these projections are the latest for the Denver Metro area. The DRCOG projections extend to 2035. The projections from 2035 to 2050 apply half the average annual growth rate of the 2030 to 2035 period.

The 2030 employment by place of work projections obtained from DRCOG in 2010 are 8 percent higher than the same projections prepared by DRCOG for the 2002 water demand projections. The current projections assume a 1.25 percent average annual growth rate to 2030. To evaluate this assumption, HE reviewed the Statewide Water Supply Initiative (SWSI) employment projections prepared in 2010. For the Denver Metropolitan Area, these projections assumed a 1.48 percent average annual growth rate to 2030, validating the DRCOG assumption. This is also consistent with the trends toward new urbanism, where employment centers are concentrated in the urban core.

Overall, the updated economic and demographic data Denver Water provided to HE and utilized to update their water demand projections are appropriate and the underlying assumptions are reasonable. The statistics come from the best available sources, and when a specific statistic is unavailable for certain years, it is estimated using the most suitable method.

In addition to the variables called for in the forecasting models, Denver Water also provided population and household projections. The 2032 population projections for the Denver Water Service area are down slightly from the projections produced in 2002. Despite the economic challenges which occurred periodically in the 2010 decade, population in the Denver Water combined service area actually increased by 12 percent. With increasing urbanization and household density, population is expected to continue to grow at somewhat less than one percent as an annual average through the 2032 forecasting horizon.

The water demand projections are based upon the application of the updated independent variables to each of the three sub-models for the water demand projections. The water demand sub-models indicate that single family water demand projections are about three percent less than the 2032 projections produced in 2002. This is largely due to reduced household income

projections and lower population growth projections. However, the commercial and industrial water demand model and the governmental and institutional demand models point to an increase in water demand projections of more than nine percent because of increases in employment projections in the Denver Water combined service area. Overall, the treated water demand projections, after calibration and system adjustment, amount to about 346,000 acre-feet by 2032. Given the updated projections of economic and demographic variables, these water demand projections are considered reasonable.

### **Incorporation into FEIS**

Based upon HE's determination that the updated economic demographic projections and the associated water demand projections are reasonable, the results have been incorporated in the FEIS. The final projections also account for natural replacement, conservation and fixed contracts similar to the 2002 projections. In conclusion, the updated water demand projections are suitable and appropriate for the FEIS.